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Model Curriculum for Training Tractor-Trailer Drivers

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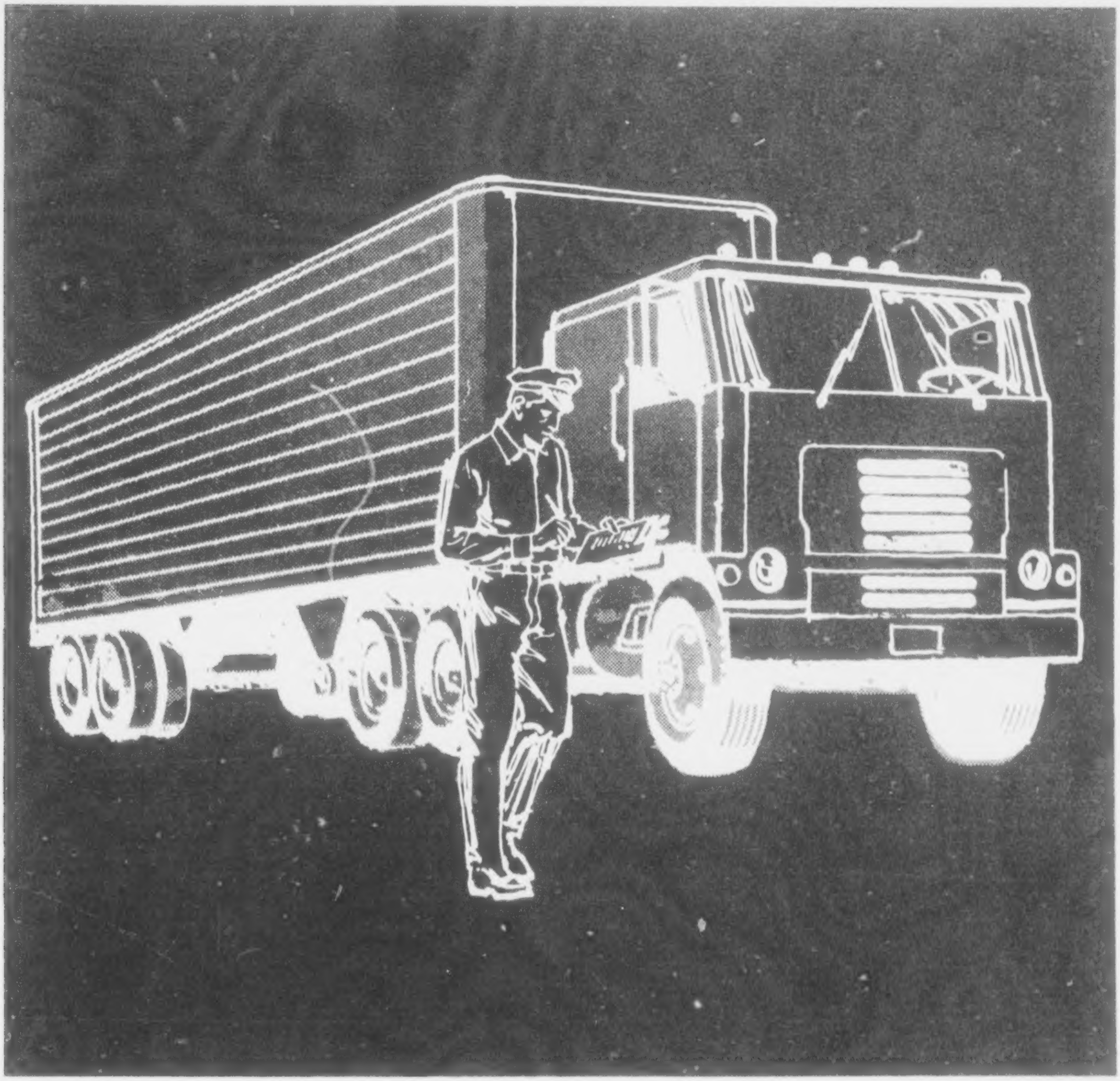
Instructor's Manual

Part Two



U.S. Department of Transportation
Federal Highway Administration

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Model Curriculum for Training Tractor-Trailer Drivers

Bureau of Motor Carrier Safety

1985

Instructor's Manual
Part Two

U.S. Department
of Transportation

**Federal Highway
Administration**

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UNIT 2.4
SPACE MANAGEMENT

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PURPOSE

The purpose of this unit is to enable students to manage the space required for safe vehicle operation.

OBJECTIVES

Performance Objectives

Students must be able to

- select a lane offering best mobility and least traffic interruption, in accordance with the law, to cause minimum interference to vehicles.
- assure a safe gap before changing lanes, passing other vehicles, merging and crossing or entering traffic.
- position vehicle correctly within lane and relative to crosswalks so as to minimize hazards to other road users.
- position the tractor and trailer appropriately in initiating and completing a turn so as to prevent other vehicles from passing on the wrong side and to minimize encroachment on other lanes.
- maintain a following distance appropriate to traffic, road surface, visibility, and vehicle weight.
- maximize separation from traffic when vehicle is disabled.
- avoid structures having inadequate overhead clearance.

Knowledge Objectives

Students must know

- State regulations concerning commercial vehicle following distances, lane use, changing lanes, and passing other vehicles.
- the appropriate following distance for various conditions.
- the importance of maintaining maximum separation from other vehicles to ensure room to maneuver in responding to errors of other drivers.
- the importance of checking position of one's own vehicle and other road users by use of mirrors.
- dangers created by overhead obstructions.

Skill Objectives

Students must be able to judge adequacy of gaps for passing, for crossing and entering traffic, and for changing lanes.

Attitude Objectives

Students must believe that

- maintaining maximum separation from other vehicles increases the opportunity to respond safely to driver errors.
- proper position of the vehicle is important to prevent collisions.
- it is the driver's responsibility to position the vehicle in such a way as not to impede or conflict with other road users.
- intimidating other road users by allowing inadequate space is illegal, unsafe, and detrimental to public relations.

LESSONS

Lesson 1.	**Space Management Principles (Classroom)**	**1 hour 45 minutes**
Lesson 2.	**Application of Space Management (Street)**	**6 hours**

LESSON 1 SPACE MANAGEMENT PRINCIPLES (CLASSROOM)

Overview

Time Allotted: 1 hour 45 minutes

Prerequisites: Unit 2.3, Lesson 1

Purpose:

The purpose of this lesson is to present and discuss the principles of space management in order to prepare students to apply them on the road in the next lesson of this unit.

Materials

Instructional Aids

Visuals 1 to 22

Student Material

Timed Internal Driving, in Unit 2.4 of Student Manual

Instructor Material

Dimension of vehicles used in school as added examples in discussion of gap selection and other space management techniques.

State law requirements for minimum following distances (if applicable)

Content

Activity or Topic	Approximate Time
1. THE IMPORTANCE OF SPACE MANAGEMENT	8 minutes
2. SPACE AHEAD	30 minutes
3. SPACE ABOVE	7 minutes
4. SPACE TO THE SIDES	20 minutes
5. SPACE FOR TRAFFIC GAPS	20 minutes
6. GIVING SPACE TO OTHERS	20 minutes
	1 hour 45 minutes

1. THE IMPORTANCE OF SPACE MANAGEMENT (8 minutes)

Visual 1 Space Cushion

Space Cushion

Driver Needs Time and Space to Maneuver to Avoid Conflicts

Change speed
Stop
Change vehicle direction

Space Cushion needed to Allow Maneuvering Time and Room

Definition: Adequate space on all six sides of the vehicle
1 Ahead
2 Behind
3 Left
4 Right
5 Above
6 Below (underclearance)
Techniques easy to learn
Frequently violated
EXAMPLE: Tailgating, one of most common

Maneuvers Severely Affected if Space Cushion is Inadequate

EXAMPLE: No space available on either side of your rig
Vehicle ahead forced to stop
Tractor-trailer vehicle must also stop, can't change direction

EXAMPLE: Tractor-trailer following too closely
Vehicle ahead forced to stop
Following vehicle must panic stop or panic turn

Consequences
- Potential rear end collision
- Jackknife
- Run off the road
- Turnover

Give other examples of the six sides based on your own driving experiences

Visual 2 Truck Crossing Traffic: Need for Adequate Gap

Driver Needs to Understand Space Management Principles to Change Space Safely

EXAMPLES: Crossing traffic
Passing
Merging with high speed traffic

What he/she needs to know

    Vehicle characteristics that affect size of gap needed: (length, acceleration capabilities)
    How to judge adequate gap for vehicle

When it is safe to proceed
How long it will take to execute maneuver

Recap

Each driver must know how to
- Maintain adequate space cushion
- Safely execute maneuvers that require space, i.e., passing

2. SPACE AHEAD (30 minutes)

Visual 3 Tailgating

Following Distance

Problem of Tailgating

- Leading accident cause
- Rear enders are 25 percent of all accidents
- Other consequences
    - Transforms routine maneuvers into panic stops
    - Frightens car drivers
        - When tailgated by tractor-trailer
            - Car drivers become frightened/anxious
            - Increased chance of driver error
            - Bad for image of trucking industry
    - Restricted sight distance
        - (Point out the effect of limited sight distance in visual)

Following Driver Is Legally Responsible in Rear Enders

- He is the only one who can control the space between vehicles.
- He has to maintain safe following distance

Methods of Establishing Safe Following Distance

- Old method
    - One vehicle length for every 10 miles of speed
        - Most drivers had difficulty in using it
        - Very difficult to judge one vehicle length when driving
        - Was not accurate, particularly at higher speeds -- what does five car lengths look like?

Visual 4 Two-Second Following Distance for Cars

2-second timed interval for cars (up to 40 miles per hour)
- How the 2-second timed interval works
  - Pick stationary marker ahead (shadow, tree, sign, etc.)
  - Start counting when rear bumper of vehicle ahead passes marker
  - Count the seconds: One thousand one, one thousand two
  - The time it takes to reach marker is the timed interval
- What it means
  - 2 seconds is the minimum safe interval for cars to follow
  - Works at all speeds up to 40 mph
    - As speed increases, the distance covered in two seconds increases
    - Following distance is automatically increased to take into account longer stopping distances
  - For car speeds above 40 mph you must add an additional second (allows more space for see, think and react time to occur)
  - For bad weather and/or road conditions an additional second must be added to the basic 2-second interval

EXAMPLE: Car traveling 30 mph during bad weather -- 2 seconds, plus 1 second equals 3 seconds minimum needed

EXAMPLE: Car traveling 46 mph in bad weather -- 2 seconds (basic), plus 1 second (for speed above 40 mph), plus at least 1 second (for bad weather) equals 4 seconds

Remember these are the **ABSOLUTE MINIMUM TIMES REQUIRED TO GET:**
- Seeing Time (space) Thinking Time (space)
- Reacting Time (space)
- Braking Time (space)

Visual 5 Heavy Duty Vehicle Formula for Timed Interval Following Distance

Larger Vehicles Need Longer Timed Interval

- Heavy duty vehicles may require more stopping distance
- Formula for determining timed interval: 1 second for every 10 feet of vehicle length (or fraction thereof) for speeds up to 40 mph

EXAMPLE: Car equals 20 feet length or 2 seconds

EXAMPLE: Tractor-trailer
- 40-foot vehicle requires 4 seconds
- 50-foot vehicle requires 5 seconds
- 60-foot vehicle requires 6 seconds
- Round the length of vehicle up (e.g., 36-foot long rig equals 40 feet, 52-foot long rig equals 60 feet, etc.)

For speeds above 40 mph, you must add another second to the basic requirement

EXAMPLE: 50-foot rig traveling 48 mph
Basic requirement (50 feet) = 5 seconds
Above 40 mph requirement = 1 second
Total time needed = 6 seconds

For bad weather/visibility and road conditions you must also add at least another second (depending upon severity of conditions you may need to add additional seconds).

EXAMPLE: 63-foot rig traveling 55 mph in bad visibility (a dangerous practice)

Basic requirement (70 feet) = 7 seconds
Above 40 mph requirement = 1 second
Bad weather/visibility/road requirement = 1 second
Total time needed = 9 seconds

Visual 6 Conditions Requiring Extra Following Distance

Add Extra Time When Driving Conditions Require More Space in Front

Count extra second (or more) when stopping distance is increased
Slippery roads, need more stopping distance when vehicle ahead stops

Poor visibility
  Add 1 second for night driving
  1 or more seconds when weather restricts visiblity (i.e., rain, snow, fog)

When following other trucks, need extra space for sight distance

Example of increased timed interval
When highways are wet add at least 2 seconds to the basic formula
  When highwys are snow or ice covered add at least 4 (or more) seconds to the basic formula
  When bobtailing, pulling an empty trailer, pulling an unstable load, or any unevenly balanced load to increase the basic formula to compensate for it

Getting and Keeping Space in Front of Your Rig

A frequent concern of students is "If I leave that amount of space between my rig and the vehicle ahead, other drivers will pass me and go into it".

ANSWER: Yes, they frequently will and also will usually pop back out again to pass the vehicle ahead of them -- thus leaving you with adequate space once again.

It is readily conceded that oftentimes, even a professional rig driver cannot get and/or keep the space cushion that he/she needs -- but when this situation (lack of adequate cushion) does occur, the professional immediately recognizes the extreme hazard involved and becomes extra alert while taking immediate defensive action, such as slowing down, changing lanes, or whatever.

Visual 7 Managing Space to Rear by Maintaining Adequate Following Distance

Managing Space to the Rear

Cannot control following distance of vehicles behind you
Cannot see many smaller vehicles following you

Situations in Which Following Drivers Can Be a Problem:

Eager to Pass--When truck is traveling slowly (e.g., long upgrade)

Poor Visibility--In fog or snow, drivers let truck run interference. Crowd close to follow taillights.
Wet Weather--Spray from truck obscures vision

Stopping on upgrades--Roll back could result in a collision

Ways to Help Maintain Adequate Space Behind Trailer

Avoid sudden stops or other moves which affect following vehicles

Maintain safe following distance ahead
- Protects driver behind by allowing tractor-trailer driver
  - To drive smoothly
  - Time to signal intentions
  - To avoid sudden stops and moves
- Gives driver behind space to move into

When driver behind wants to pass, reduce speed
- Helps driver to pass quickly
- Opens more space in front

Legal Requirements for Following Distances

Note: Present information here about minimum required following distances for your State

Many States have established minimum required following distances, by vehicle size (i.e., number of axles), by type of road (i.e., single lane highway)

Driver responsible to know minimum distances in States he drives
Can use timed interval method to assure compliance
4 seconds meets legal requirements of all stops

Legal minimum distances shorter than recommended safe distance, using recommended time interval distance:
- Accounts for stopping distance
- Driving speed
- Road conditions

Class Discussion: Why do Some Tractor-Trailer Operators Follow Too Closely?

1. Present common reasons for tailgating

2. Show why those reasons are not valid

EXAMPLES:

Reason: To make up time
Not valid
    Speeding up, slowing down, frequent lane changing is unsafe, inefficient
    Driver exposed to more risks

    Little, if any, time is gained

Reason: To intimidate other motorists
    Not valid
        Deliberately unsafe
        Illegal
        Bad public relations for
            Trucking industry
            Driver's company
            Driver himself

Reason: To keep vehicles behind from cutting in front
Not valid
    Drivers rarely cut in or stay very long (invite students to verify it in their own automobiles)
    Driver can reestablish following distance
    Most importantly, safety is maintained

Recap

Benefits of Maintaining Safe Following Distance

Smoother and safer driving
Driver less fatigued
Saves fuel, brakes, tires -- because of the ability to operate at a constant steady speed

Consequences of Poor Management of Space Ahead

Increased chance of accident
Frequent traffic conflicts
More likely to panic stop (turnover, jackknife risk increased)
Results in stop-and-go driving
    Increases vehicle wear and tear
    Wastes fuel
    Fatigues the driver

3. SPACE ABOVE (7 minutes)

Visual 8 Space Above: Need for Adequate Clearance

Adequate Clearance Above

Overhead Clearance Problem

- Bridges and underpasses
- Low wires
- Tree limbs
- Building structures
- Overhead signs

Importance

- Many collisions with overhead obstructions result in
  - Damage to truck and private property
  - Serious personal injury or death
  - Vehicle being lodged between obstruction and load
  - Extreme embarrassment to driver -- there is no excuse for this kind of collision -- ever

Posted Clearances

- Required by law on overhead structures
- Can be reduced by road repair, snow, rough roadway
- Must be over 6 inches above the height of trailer to be considered safe
- Never trust the signs -- the road may have since been resurfaced and no one remembered to change the sign

Precautions

- Watch for obstruction and traffic warning signs
- Approach slowly -- stick you head out cab window (look up over your right shoulder)
- Get out and check when in doubt

Clearance Can Change From One Time to Another

- Wind can cause trees, signs to bend
- Ice can cause wires to sag

- Differences in trailer load affects height
  - Heavy load compresses springs
  - Can get under bridge OK when loaded
  - Then can strike that same bridge when coming back with empty trailer
  - Can also get "trapped" in warehouse the same way, e.g., loaded rig goes in OK, empty rig is too high to exit

4. SPACE TO THE SIDES (20 minutes)

Manage Space to the Sides By

Positioning vehicle properly
Compromising space
Separating hazards

Visual 9 Tractor-Trailer Width Vs. Lane Widths

Positioning Vehicle Properly

Remember Width of Vehicle and Lane Width

- Vehicle approximately 8 feet wide (mirrors may increase width)
- Width of lanes
    - 10 feet--rural and older roads
    - 12 feet--some two lanes and older roads
    - 14 feet--most modern super highways

Keep Vehicle Centered in Your Lane on Expressways

- Keep vehicle centered within lane at all times
- Avoid encroaching lanes to right and left
    - Smaller cars have more room, can "weave" within lanes
    - Tractor-trailers can't be allowed to weave
- Pay attention to the tracking of the trailer, weaving or jerky steering on driver's part can cause
    - Fishtailing of trailer
    - Trailer to drift into other lanes

Stay Closer to the Left on Two-Lane Roads

- Position wheels to left and close to center
- Move to right when being passed
- Keep in mind that there is little room to maneuver in 10-foot lane
- Avoid tendency to move to right for oncoming traffic
    - Need to remember to avoid shoulder, tree limbs, road signs
    - Smaller cars have more room to maneuver (4 extra feet)
    - Move just enough to right to assure clearance

- High crown
    - Frequent on two-lane roads
    - Causes trailer to tip to the right
    - Can cause right front corner of trailer roof to collide with trees, signs
    - Keeping closer to center provides more clearance -- but still must watchout

Visual 10 Proper Position for Taking Curves

Position Taking Curves

- Stay to the outside to compensate for off-tracking
    - Stay to left on right curve
    - Stay to right on left curve
- Proper position and speed reduces danger of side slipping into other lanes
- Avoid cutting across lanes to straighten out a curve
- Check for trailer drift on outboard side -- will be less drift if driver has set up the curve properly, i.e., braked prior to curve and then accelerated gently/steadily through it

Visual 11 Proper Position for Turns

Position When Turning

- Left turn
    - Don't encroach upon opposite lane
    - Don't swing right first, gives wrong impression of intentions
    - Be alert to vehicles squeezing by on right

- Wide right turn
    - Performed when turning into a street that is wide enough to handle large turning radius
        - Two-lane street with extra wide lanes (e.g., over 14 feet)
        - Two or more lanes in the same direction
    - Approach intersection competely in right lane. Any move to the left would:
        - Suggest beginning of left turn
        - Encourage following drivers to pass on the right
    - Begin turn when half of the rig is past the corner
    - Turn normally
        - Swing wide enough to make turn
        - Enter into far lane on multi-lane street if necessary
        - Avoid dragging right rear wheel across corner
    - Remain in lane after completing turn
        - Avoid return to right-hand lane in one continuous move
        - A through vehicle may be attempting to pass you on your right
        - Angle of tractor creates a blind spot for seeing vehicles overtaking on the right side
        - Safe to do only if position of trailer during turn has blocked right lane
    - Return to right lane when sure it is safe to do so

- Tight right turn
    - What
        - Move to left followed by right turn
        - "Buttonhook" pattern increases turning radius
    - Where
        - Turning into streets that are too narrow for continuous turn
        - Examples: Single lane street
          Alleys

- How
  - Move to left just before reaching corner
    - Swinging to the left too early will invite small vehicles to come between truck and curbs
    - Time swing to left so trailer blocks right side
  - Enter cross street slowly, yielding to oncoming vehicles in left lane
  - Enter right lane as quickly as possible
  - Path into cross street may be blocked
    - Often necessary for truck to encroach upon opposing lane
    - Vehicle waiting or approaching in opposing lane may block path
    - Wait for other vehicle to back up or move further left
    - Don't try to back the truck
    - When a tractor-trailer is in the opposing lane, driver is responsible for avoiding an accident

- Turning alongside
  - Two or more lanes may be provided for turning traffic
  - Tractor-trailer should use the outside lane as shown
    - Left most lane in right turn
    - Right most lane in left turn
  - If inside lane is used adjacent driver won't anticipate outward swerve of rig
    - Other driver may stay in lane
    - Possible collision with tractor or trailer

Visual 12 Splitting the Difference Between Two Hazards

Splitting the Difference

When approaching fixed hazards on both sides, split the difference between them

EXAMPLE: Driving in city traffic

- Hazard to right: parked cars
  - Car can pull out
  - Pedestrian or bicyclist can come out from between parked cars

- Hazard to left: oncoming vehicles
  - Truck cannot encroach
  - Won't give them enough room

- Solution
  - Split the difference between hazards
  - Steer course halfway between Gives some space on each side
  - Gives some space on each side

Visual 13 Separating Hazards: Right Turn

Separating Hazards

When approaching moving hazards, take them one at a time

EXAMPLE: Making sharp right turn

Hazard to right: Curb requires swinging wide in turn
Hazard to left: Oncoming traffic bars wide swing
Separate hazards
    Wait for oncoming traffic to pass, then
    Swing left far enough to avoid curb

Visual 14 Separating Hazards: Bicycle

EXAMPLE: Approaching bicyclist on right with oncoming vehicle on left

Separate the hazards:
    Slow down
    Let oncoming truck pass
    Move to the left and pass bicyclist

Visual 15 Separating Hazards: Problem

Problem-Solving Discussion

Describe Situation Then Ask and Discuss Questions

Situation

You are approaching an intersection. There is a man stopped to change a tire just ahead. And, there is a tanker pulling out into traffic from the intersection. There is a truck approaching in the left lane.

Questions and Answers

Q. What is the best thing for you to do?

A. Slow down and let oncoming truck pass. Move slightly to left when passing man changing tire.

Q. What is the worst thing you could do? Why?

A. Speed up and try to pass man changing tire before oncoming truck does. Because tank truck will take a long time to get up speed and you will have to slow down for him anyway. Also, you may reach man changing tire at same time as oncoming truck does. Neither of you will have any maneuvering room if anything happens (e.g., tire rolls into road or man steps in the roadway).

5. SPACE FOR TRAFFIC GAPS (20 minutes)

Definition of Gap

Open space in traffic
Need safe gaps to
    Pass vehicles
    Enter traffic

        - Cross traffic
        - Merge into traffic

Difficult Skill to Learn

- Must learn how to judge adequacy of gaps
    - When is it safe to go?
    - How long will maneuver take?
    - Takes experience for car drivers to learn how to judge gaps

- Tractor-trailer operator needs to relearn that experience due to differences in vehicle
    - Size
    - Handling

Differences Between Car and Tractor-Trailer for Handling Gaps

Increased Size Requires Larger Gaps

- Length:
    - 60-foot combination 3 times longer than car
    - Need longer break in traffic
- Width:
    - Twice as wide as car
    - Affects size of gap when passing

Increased Weight Causes Low Acceleration

- Need to know effect of weight on acceleration capability of vehicle
    - Acceleration depends on weight of rig
    - Weight increase means longer acceleration decrease
    - Fully loaded vehicles take longest to accelerate

High Center of Gravity

- Potential for tipover if vehicle improperly handled
    - Turned too sharply or quickly
    - Jerky steering

Articulation

- Scrubbing of tandems on pavement reduces acceleration
- Fishtailing if turning too fast

Summary

- To judge and maneuver into gaps successfully, driver needs to learn:
    - Affects of size of vehicle
    - Acceleration capabilities of different vehicles and different loads
    - Vehicle handling characteristics

Situations Requiring Adequate Gaps

Crossing and Entering Traffic

- Dangerous maneuver because of size and slow acceleration of rig
- No place for oncoming vehicle to go if tractor-trailer
  - Fails to clear intersection fast enough
  - Forced to stop by stopped vehicles

Visual 16 Gaps for Crossing and Entering Traffic

Need two safe gaps to cross traffic
- Gap in traffic being crossed
- Safe gap in lane beyond

Time consuming maneuver
- Takes 6-8 seconds to cross street or highway
- Takes up 10-12 seconds for large vehicle to turn into the left lane
- Could take longer for fully loaded vehicle
- Need large enough gap
- Car going 55 travels 810 feet in 10 seconds
- Need a gap of 810 feet (equal to 1-1/2 city blocks)

Use proper search techniques to assure adequate gaps, i.e., look left-right-left

Be patient
- Difficult to get gaps needed
- Wait for gaps (don't bluff through with size)
- Quick starts and turn could be dangerous

Visual 17 Gaps for Passing

Passing

- Need three gaps
  - Oncoming gap
  - Gap ahead
  - Gap behind

Oncoming Gap

- How much clear road is needed?
  - Factors
    - Difference in speed between truck and vehicle being passed
    - Length of both vehicles
    - Actual speed of both vehicles

EXAMPLE: Tractor-trailer at 40 mph passing car at 35 mph
Time needed for safe pull out, passing distance and return, about 15 seconds
Two vehicles traveling toward one another at 40 mph cover about 1/3 mile

- Safe pass requires clear road ahead for at least 1/3 mile
  - Distance increases as speed goes up tractor-trailer at 50 mph car at 45 mph
  - Total clear road ahead needed: almost 1/2 mile

- Hills or curves
  - Restrict sight distance
  - Cannot see needed 1/3 to 1/2 mile ahead
- Intersections
  - Other vehicles might move into right lane and prevent return
  - Driver from left may make right turn into opposing lane without looking downstream
- Oncoming traffic
  - Difficult to judge distance
  - Appear to be standing still at far distances
  - When they appear to actually move towards you they are too close

Gap Ahead

- Maintain normal following distance prior to passing
- Avoid anticipatory acceleration (building up speed in advance)
  - Not necessary if gap is sufficient
  - Potentially dangerous
    - Forces abrupt pullout in order to pass
      - Can cause fishtailing
      - Trailer could strike car being passed
    - Could cause rear ender if pass must be aborted

Gap Behind

- Check right sideview mirror to assure adequate gap
  - Shadows of truck and car may be visible
  - Don't trust signals, even from other trucks
- Remember distortion of mirror (e.g., convex mirrors can "see" vehicles before it is safe to return)
- Signal return and allow enough time for other driver to respond

Visual 18 Cutting Off Vehicle with Trailer on Return from Passing

- Many accidents occur while returning to lane
  - Trailer collides with vehicle being passed
  - Many drivers unfamiliar with
    - Added length of trailer
    - Handling characteristics of trailer

Summary

Make sure there is enough clear space ahead before passing

Don't pass:
- If sight distance ahead is blocked by hills, curves
- If space ahead is threatened by inersections, oncoming vehicles
- Be sure there are adequate gaps
  - Oncoming vehicles
  - Ahead
  - Behind

Visual 19 Merging onto the Highway

Merging

Trucks need larger gaps to enter traffic than cars
Takes longer to get up to speed of flow of traffic
Total length of vehicle longer

Procedure: Merging into gaps

1. Look for gap
   - Try to spot gap at the beginning of access ramp or lane
   - Angle of approach may allow driver to view highway
   - Finding gap early, allows entire access ramp/lane for adjusting speed

2. Signal for gap
   - Signaling helps to create a gap
   - Emphasizes intent to merge
   - Other drivers more likely to yield to truck

3. Align rig
   - How to see gap
   - Align rig parallel to main roadway
     - Move as close to left edge of through lane as possible
     - Turn to run parallel to main roadway
     - Allows mirror to show main roadway rather than ramp behind

4. Find gap
   - Use mirror to locate gap
     - Attempt to locate gap found earlier
     - If not possible, find the best available gap
   - Allow for distortion of convex mirror

5. Adjust speed
   - Slow up enough to allow gap to catch up to truck
   - Maintain sufficient speed to be able to merge without slowing traffic
   - Do not stop on ramp to await gap

6. Enter gap
   - As gap approaches, pull smoothly into it
   - Use first available gap; minimize chance of having to stop at the end of the ramp
   - Most times drivers will yield to truck
     - Slow down
     - Change lanes
   - Stop only if necessary to prevent an accident
     - Don't barge on the highway
     - Entering vehicles always required to yield the right of way

Visual 20 Tractor-Trailer at Railroad Crossing

Railroad Crossing

Most dangerous example of needing adequate gap
Many serious accidents occur at railroad crossing each year

Procedure

- Slow down as for any dangerous intersection
  - Could be malfunctioning even if no signal to stop
  - Look and listen
    - Look both ways
    - Open windows to listen
- Stop
  - If signal tells you
  - If you are required by law (carrying certain hazardous material) If you see/hear train coming
    - Pull to right
    - Stop within 15 feet no more than 50 feet
    - Check for safety before going
    - Don't shift when crossing tracks (could stall)

- Signal intent to stop
  - Following vehicles don't expect stop
  - Stopping at crossings a frequent cause of accidents

NOTE: This is a key area where space below may not be adequate (low trailers may get hung up on tracks)

Recap

Time/experience needed to judge safe gaps when driving combinations

Keep in mind differences with car
- Size
- Acceleration
- Capabilities
- Handling characteristics

Don't bluff through because of size

Accelerate smoothly, avoid quick or jerky steering to decrease potential for
- Tipover
- Trailer drift

6. GIVING SPACE TO OTHERS (20 minutes)

Visual 21 Right-of-Way: Rules and Situations

Principles of Right-of-Way

Law does not give any driver "right-of-way"

Only indicates who should yield right-of-way in various situations

No matter who should yield right-of-way, every driver should be prepared to
- Stop
- Slow down
- Change directions

Basic safety rule: Whoever has last clear chance to prevent accident must do so

Primary Right-of-Way Rules

- Drivers on left must yield to drivers on right
- At 4-way stop, vehicle that stops first goes first

- Turning
    - Driver turning at intersection yields to those going straight
    - Driver turning left yields to one turning right

- Yield to emergency vehicles
    - Pull over to the right at sound of siren
    - Fast moving emergency vehicles need more space to maneuver

Visual 22 Avoid Hindering Traffic

Avoid Hindering Traffic

Heavy vehicles can hinder traffic because of size and slowness

- Laws restricting right-of-way or driving practices vary by States, e.g., truck restricted to certain lanes, not allowed to pass, not allowed on certain roads, etc.

- Driver must be familiar with laws of each State he drives in

- Common situations in which to avoid hindering other traffic

Multi-Lane Roads

- Multi-lane highways
    - Keep to the right except when turning left
    - May be legally restricted to right
- Expressways, stay out of left (speed lane) except to pass
    - Need frequent access to right lane because of inclines
    - May get trapped in left when approaching hill
        - Cause very dangerous lane changing situation
        - Or hinder traffic behind

Upgrades

- Keep to the right
- Use truck lanes if available

Passing

- Don't pass on hill
- Don't pass another heavy vehicle when only slight speed differential
    - Dangerous
    - Annoys other drivers
    - Hinders traffic
    - May be illegal

- Don't tailgate before passing
  - Unsafe and not a proper passing procedure
  - Violates basic space management principles

Being Passed

- Move into the right lane
  - When law requires it
  - When it's obvious you are hindering traffic
- Slow to allow an overtaking tractor-trailer to complete pass
- Pull off road if traffic behind piles up (if safe to do so)

Crossing Traffic

- Make sure there's enough room for tractor and trailer to clear traffic before starting across
- Impeding cross traffic is illegal and poor public relations

Other Tractor-Trailers

Convoys or packs hinder traffic

- Often formed
  - When groups of vehicles are dispatched together
  - Informally at truck stops
- Pull off or pull back and avoid convoys or packs

Loading

- Many truckers double or illegally park to load/unload
- Inconsiderate and illegal in many cases

Discussion of Space Management Principles

End this lesson with a brief discussion of space management principles using the questions below.

Questions for Discussion

What are some examples you have seen of poor space management by tractor-trailer operators? Such as lack of space ahead, behind, left, right, above, below, e.g., tailgating, improper passing, parking, etc.

Describe the circumstances.

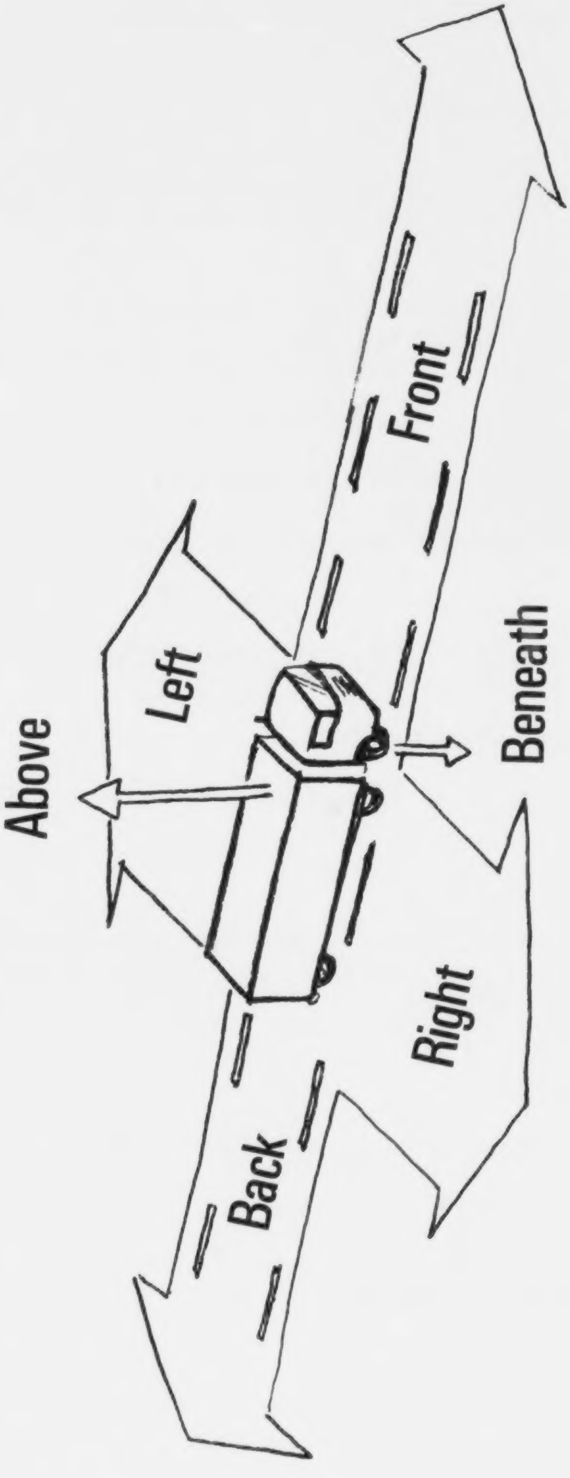
Did an accident or near miss result because of the driver's action?

How was traffic hindered?

How did this type of driving affect safety? How does it affect the image of the tractor-trailer driver?

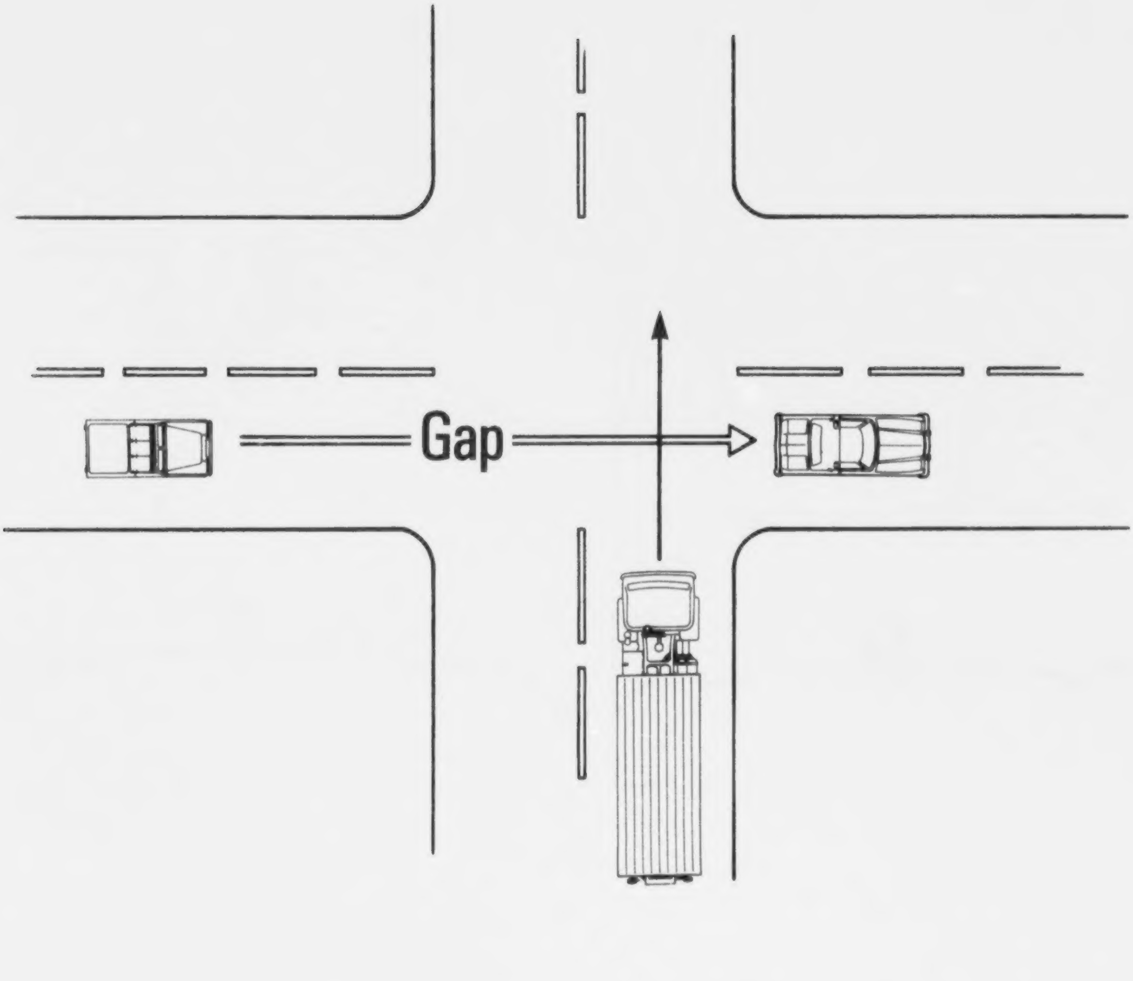
Visual 1

Space Cushion


Above
Left
Front
Beneath
Right
Back

Visual 2

Truck Crossing Traffic: Need for Adequate Gaps

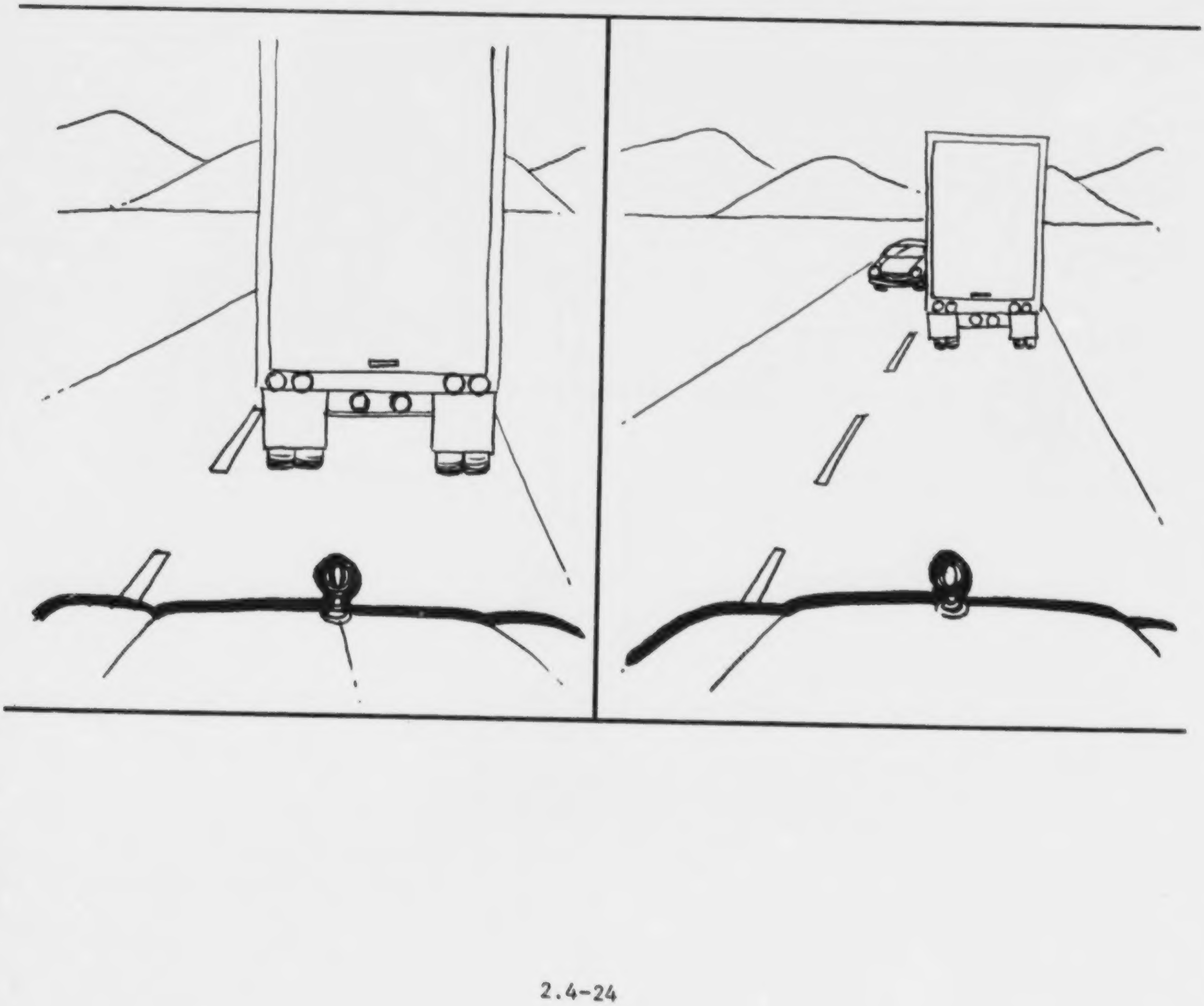


Visual 3

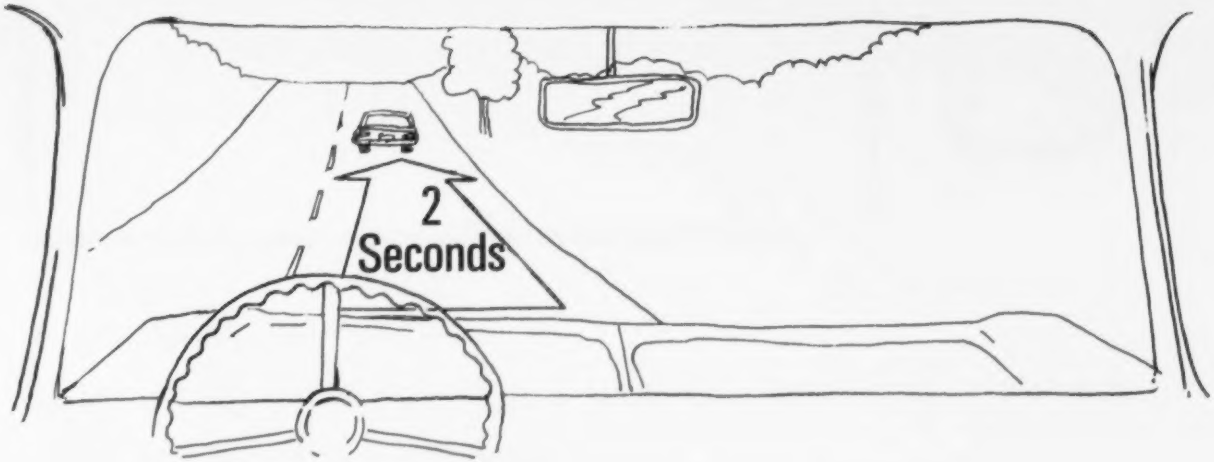
Tailgating

Causes

- 25% of All Accidents
- Panic Stops
- Frightened Car Drivers
- Restricted Sight Distance

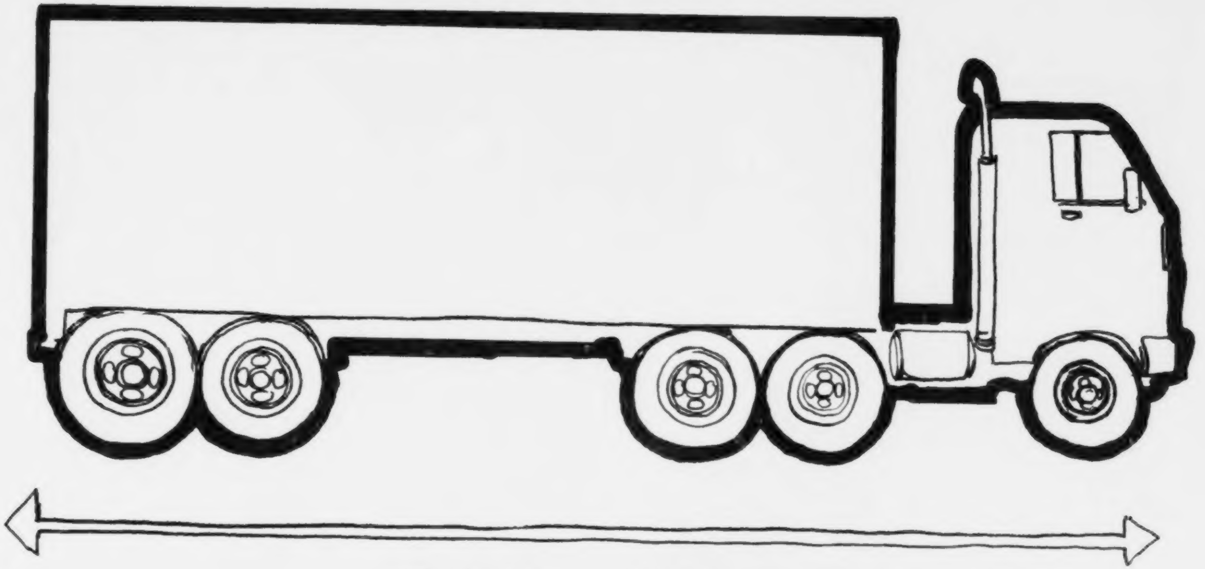


Two-Second Following Distance



Heavy Vehicle Formula for Timed Interval Following Distance

- 1 Second Required for Each 10 Feet of Vehicle Length – at Speeds Under 40 MPH
- Above 40 MPH Use Same Formula, Then Add 1 Second for the Additional Speed



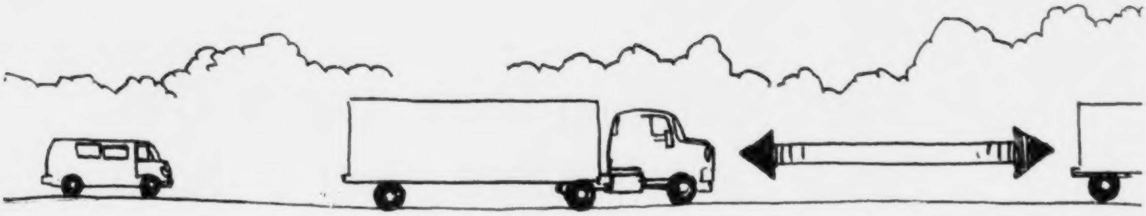
55 ft Rig = 6 Seconds

Conditions Requiring Extra Following Distance

- Slippery Roads
- Poor Visibility
- When Following Other Trucks That Block Long Distance View of Road Ahead
- Night Driving

Visual 7

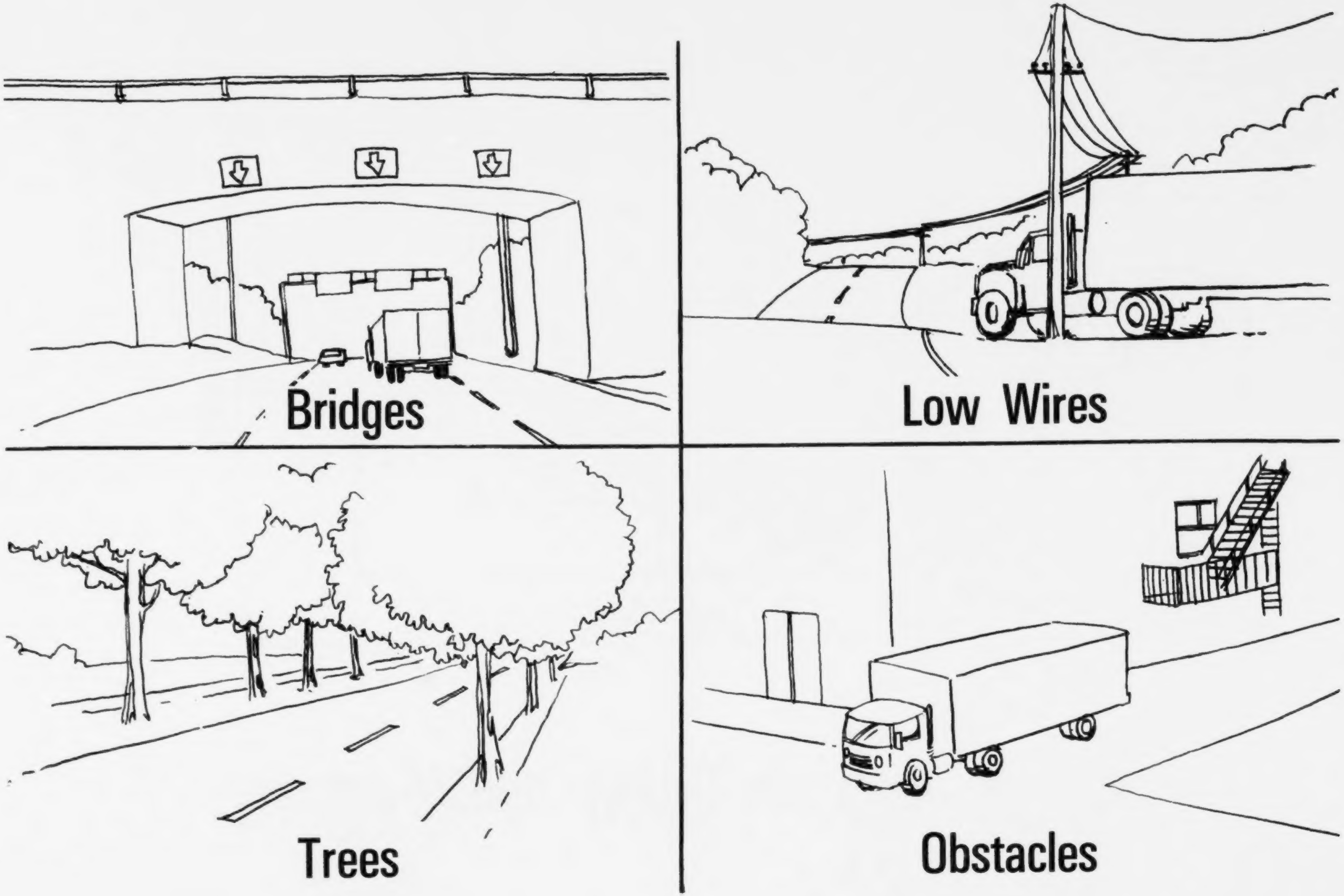
Manage Space to the Rear by Maintaining Adequate Following Distance



- Drive Smoothly
- Signal Intentions
- Avoid Sudden Moves
- Give Driver Space Ahead

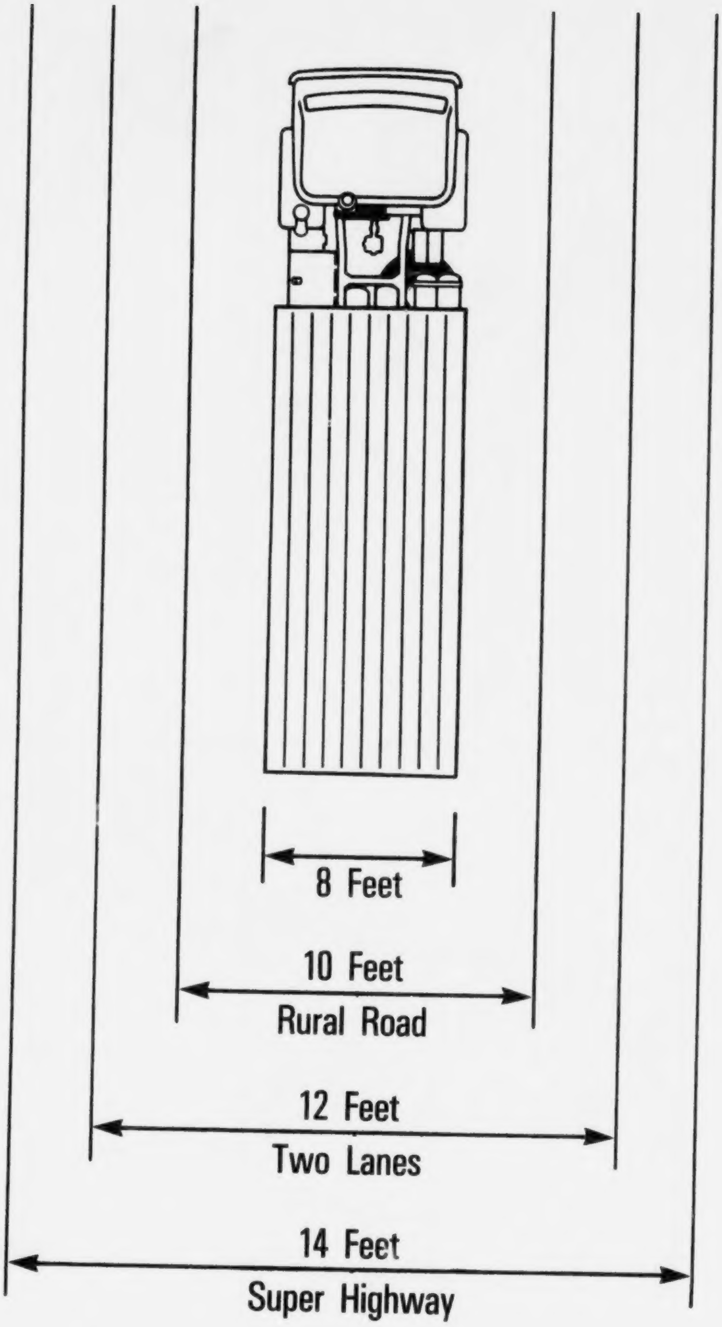
Visual 8

Need for Adequate Overhead Clearance


Bridges
Low Wires
Trees
Obstacles

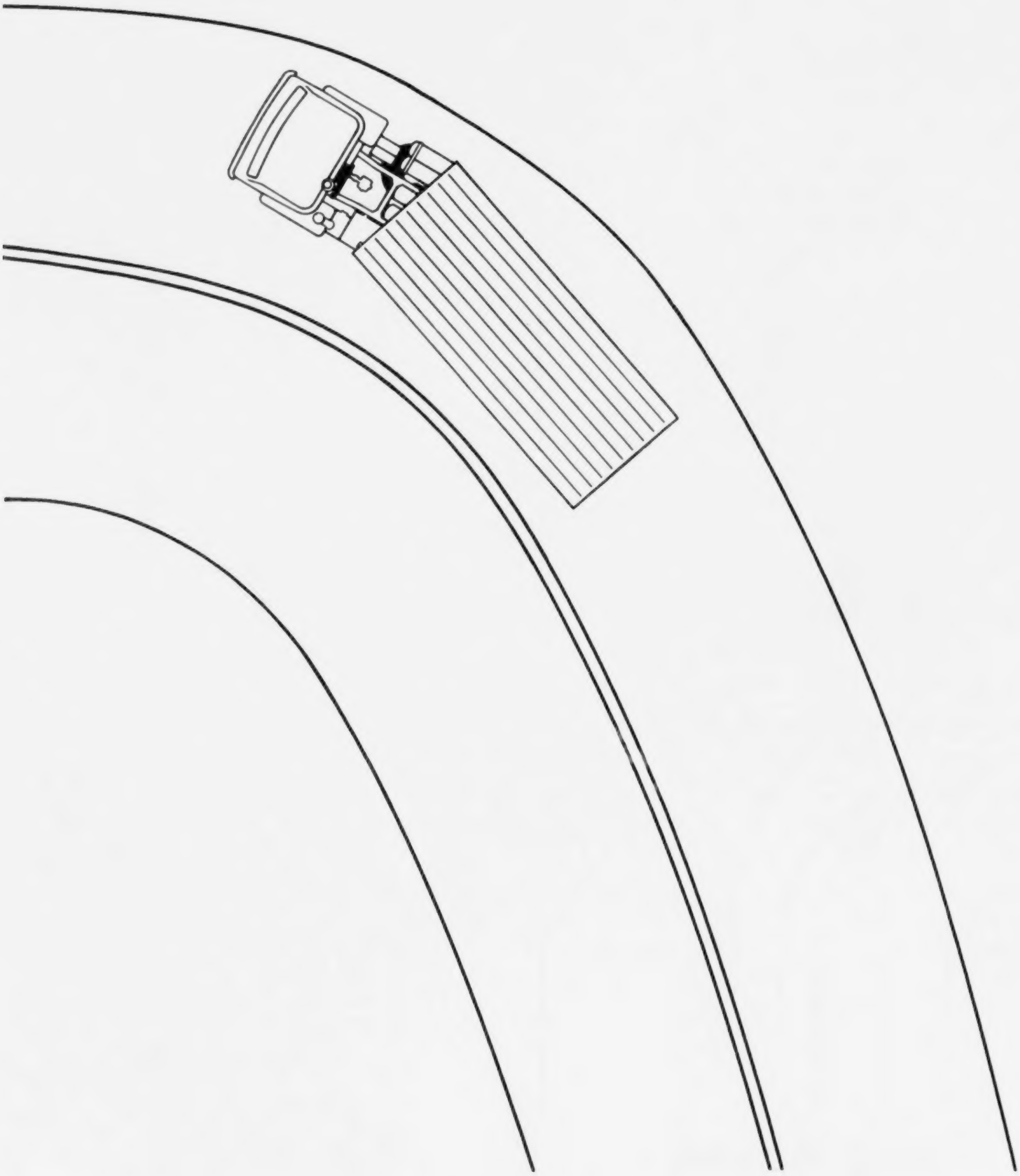
Visual 9

Tractor-Trailer Width vs. Lane Widths


8 Feet
10 Feet
Rural Road
12 Feet
Two Lanes
14 Feet
Super Highway

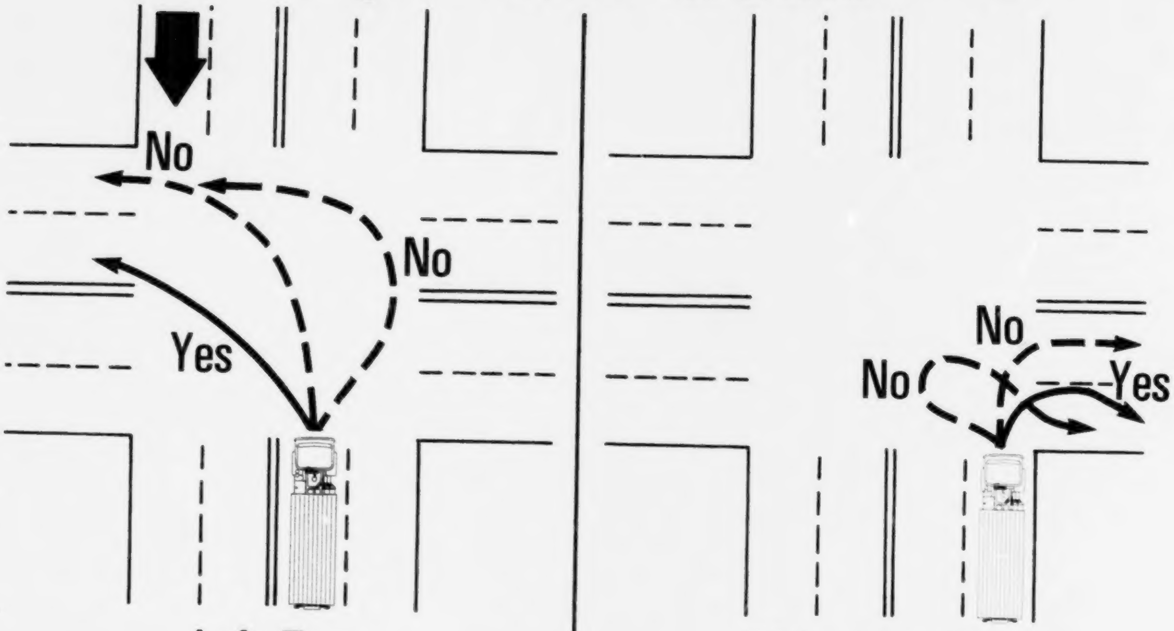
Visual 10

Proper Position for Taking Curves



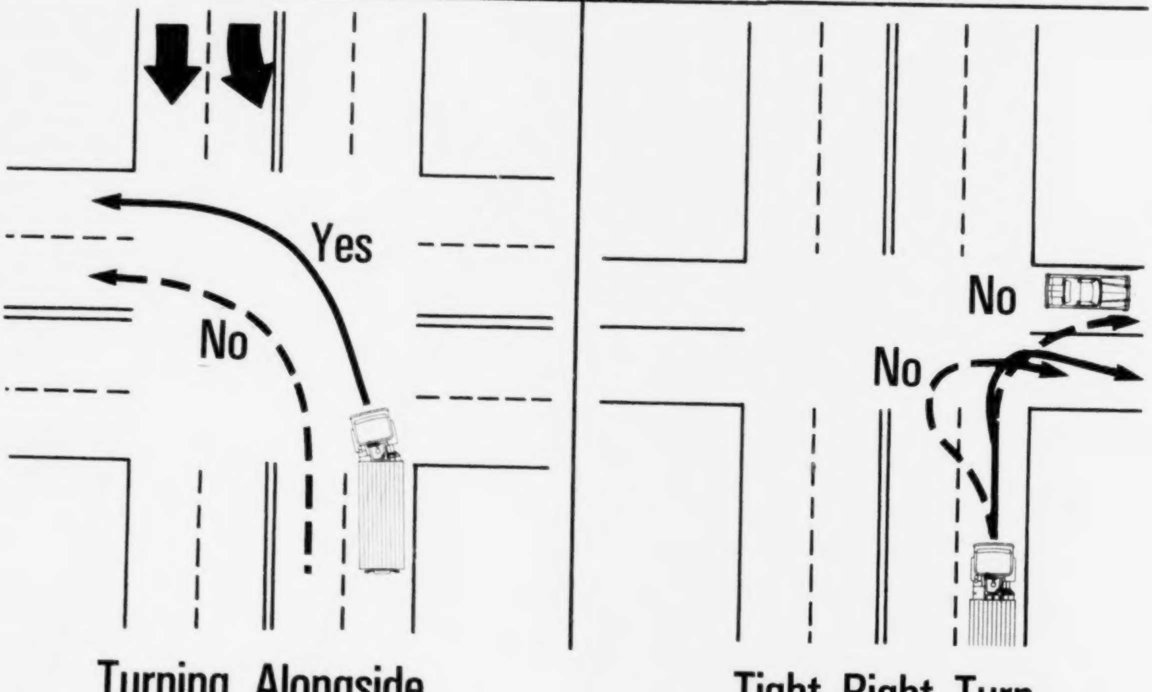
Visual 11

Proper Position for Turns


No
No
Yes
No
No
Yes

Left Turn

Wide Right Turn

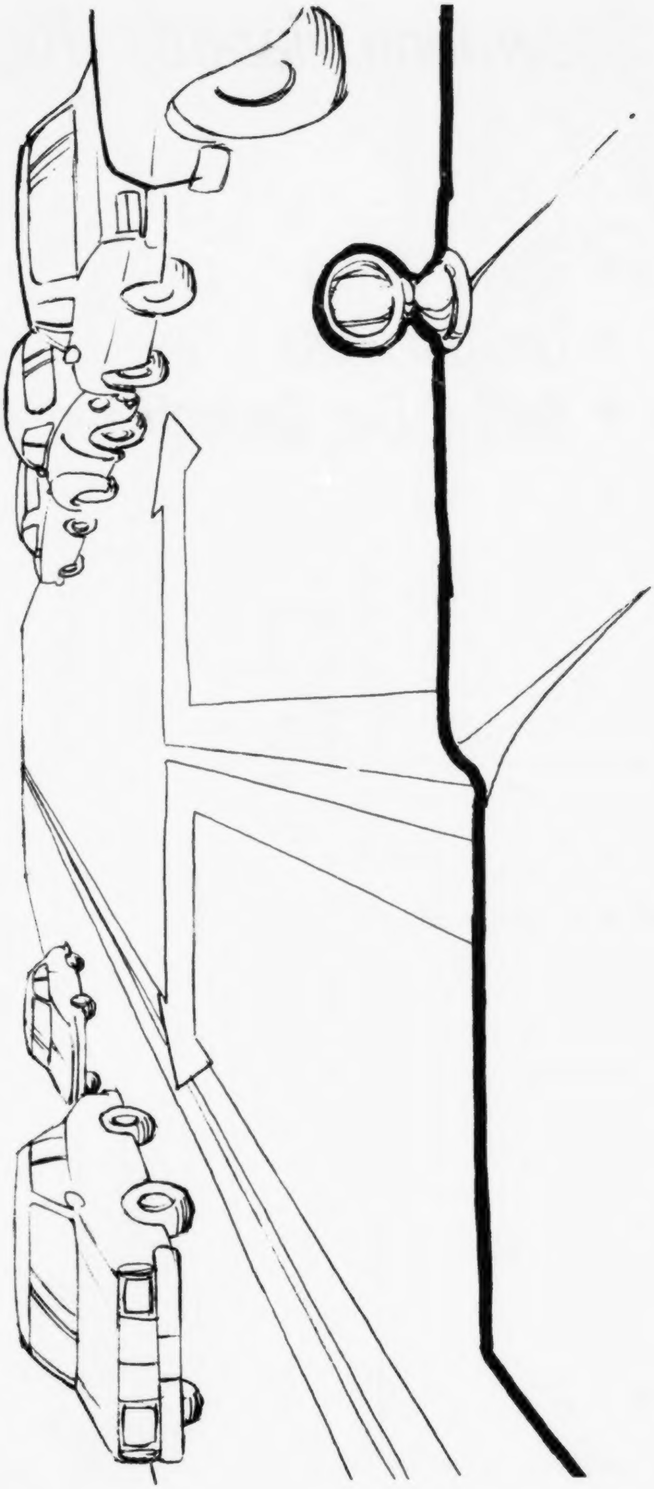


Turning Alongside

Tight Right Turn

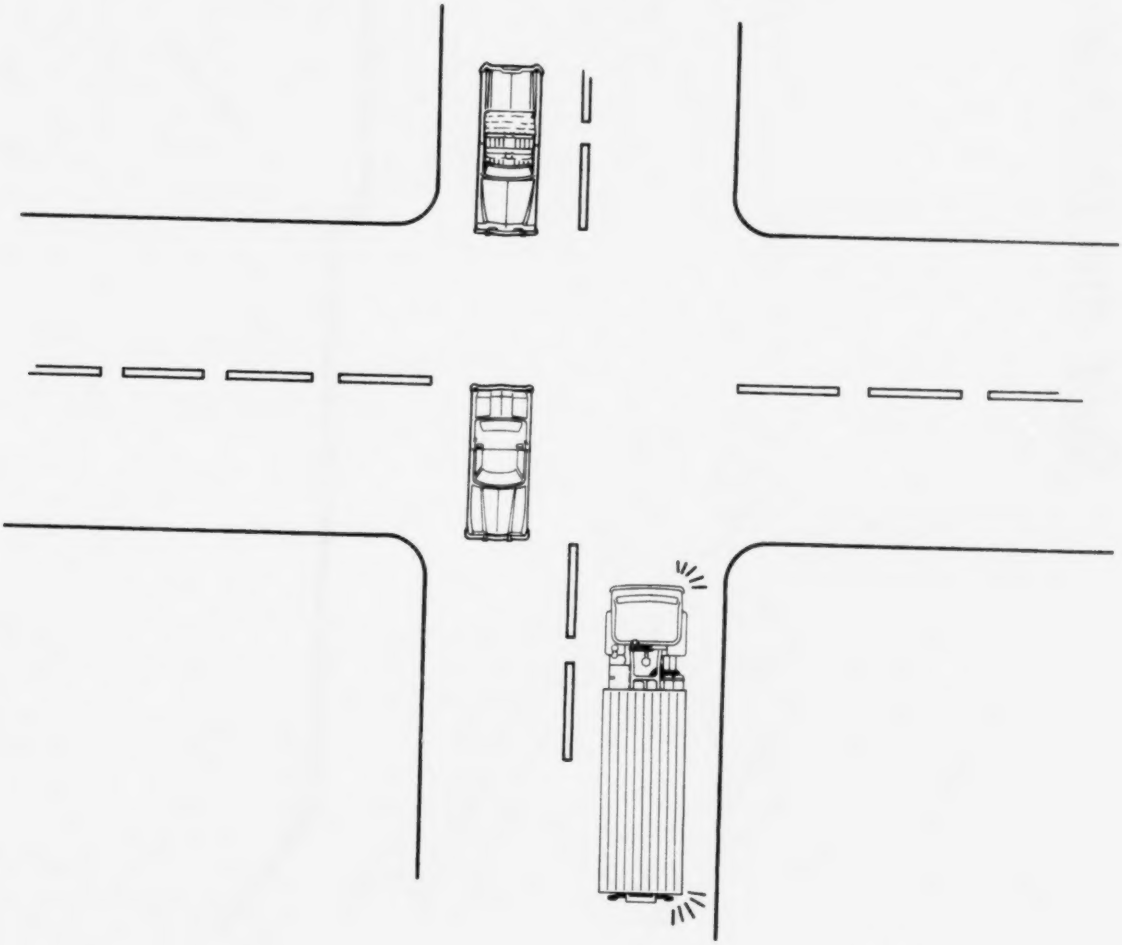
Visual 12

Split the Difference

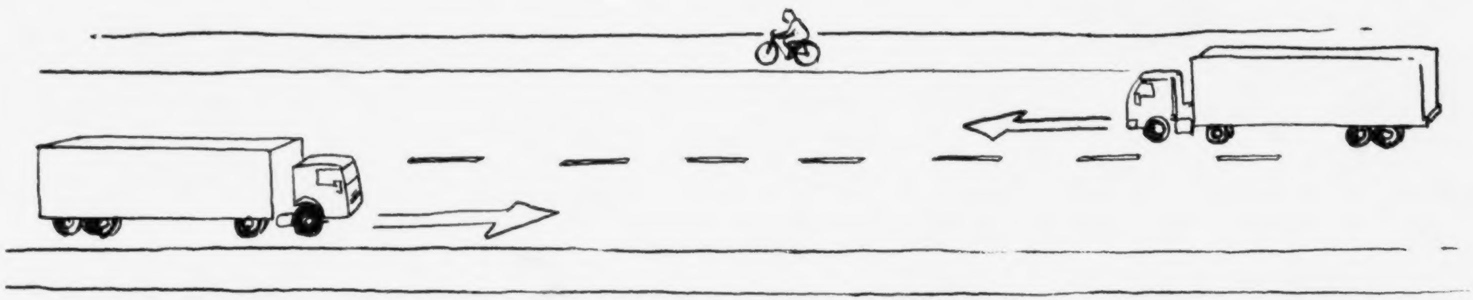


Separating Hazards: Right Turn

- Slow Down
- Let Car Pass
- Swing Out Enough for Left Turn

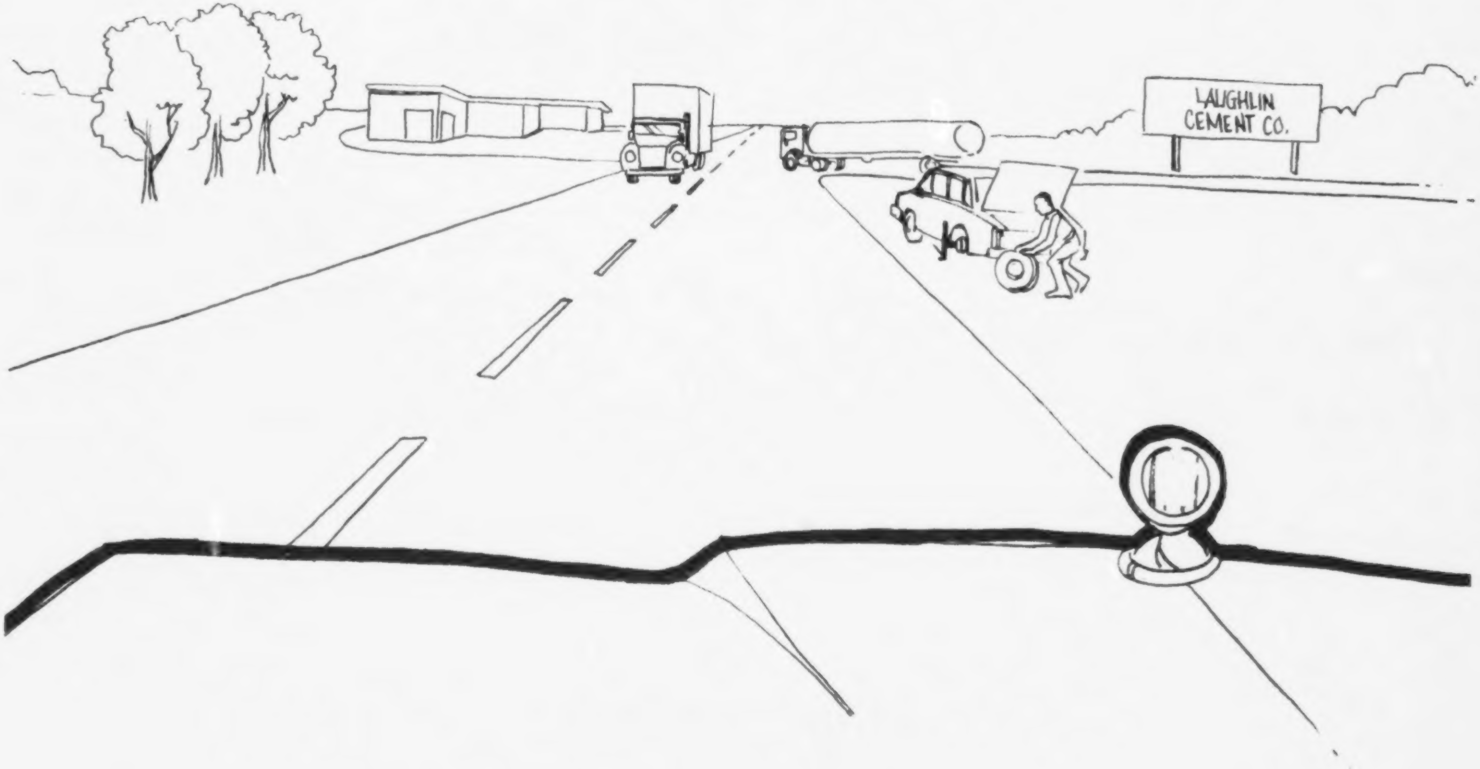


Separating Hazards: Bicycle Rider



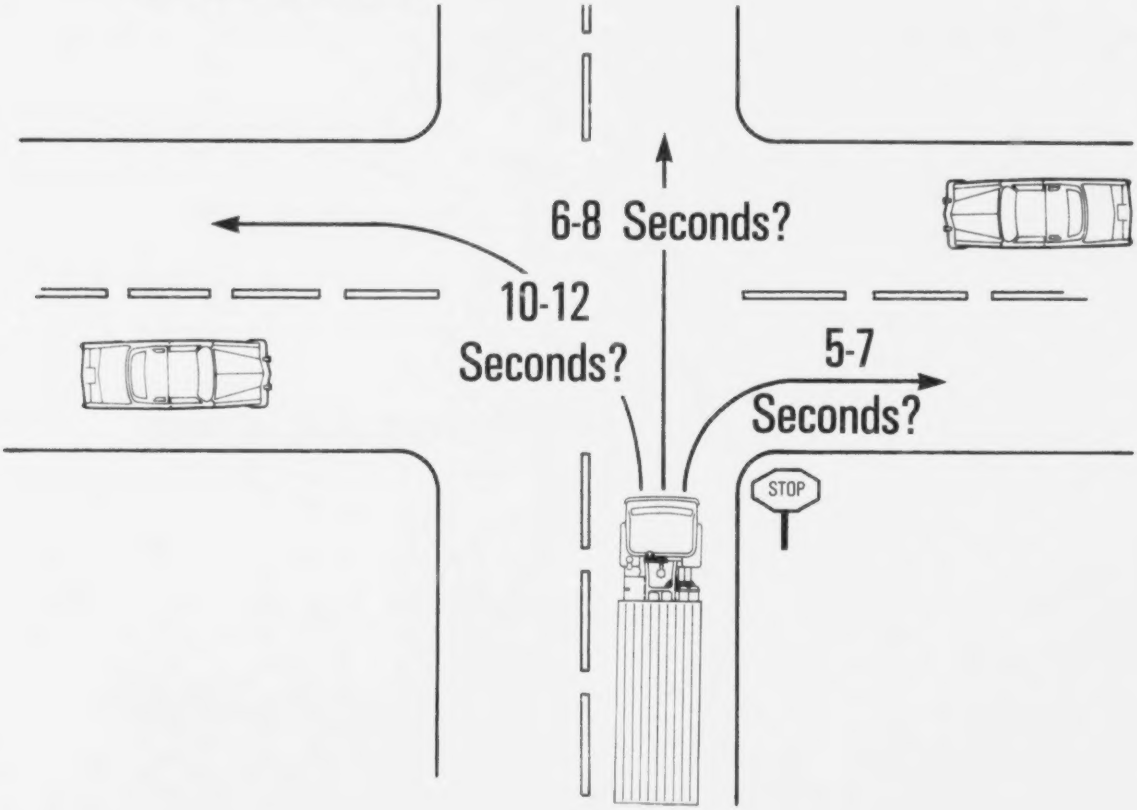
- Slow Down
- Let Other Truck Pass
- Move to Left for Bicyclist

Separating Hazards: Problem


LAUGHLIN
CEMENT CO.

Tractor-Trailers Need Larger Gaps

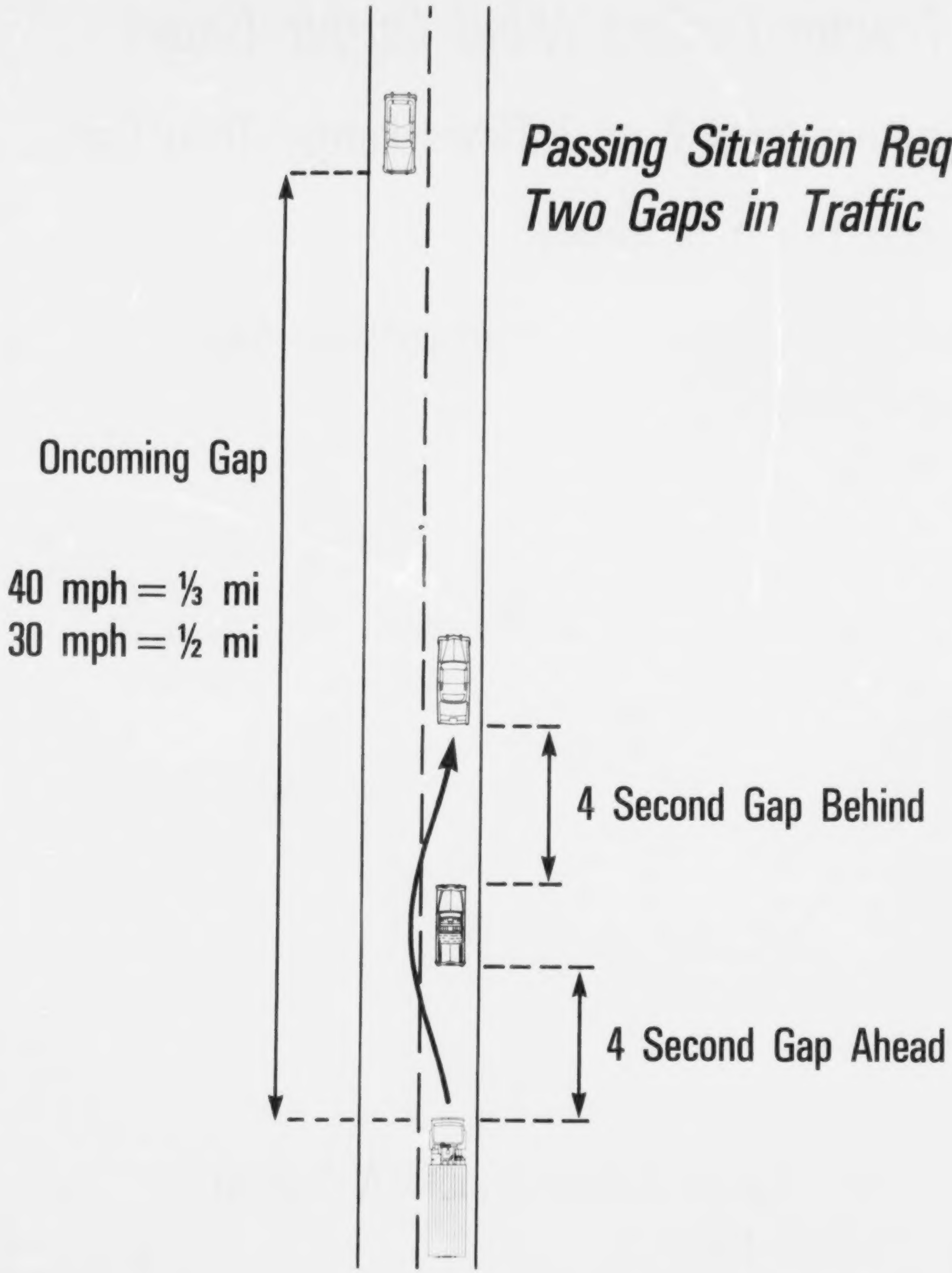
- Combinations 2 or 3 Times Larger Than Car
- Acceleration Is Slower
- Center of Gravity and Articulation Must Be Considered


6-8 Seconds?
10-12 Seconds?
5-7 Seconds?
STOP

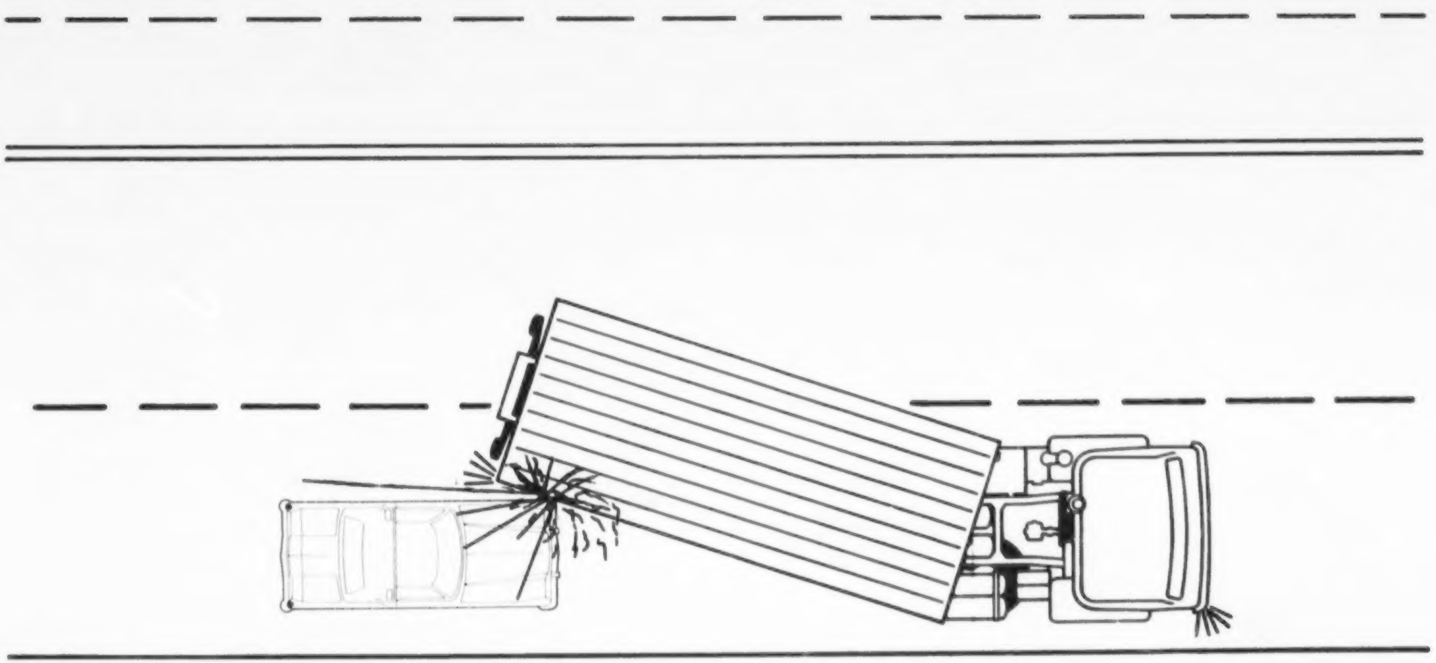
How Large A Gap Should A Tractor-Trailer Have?

Visual 17

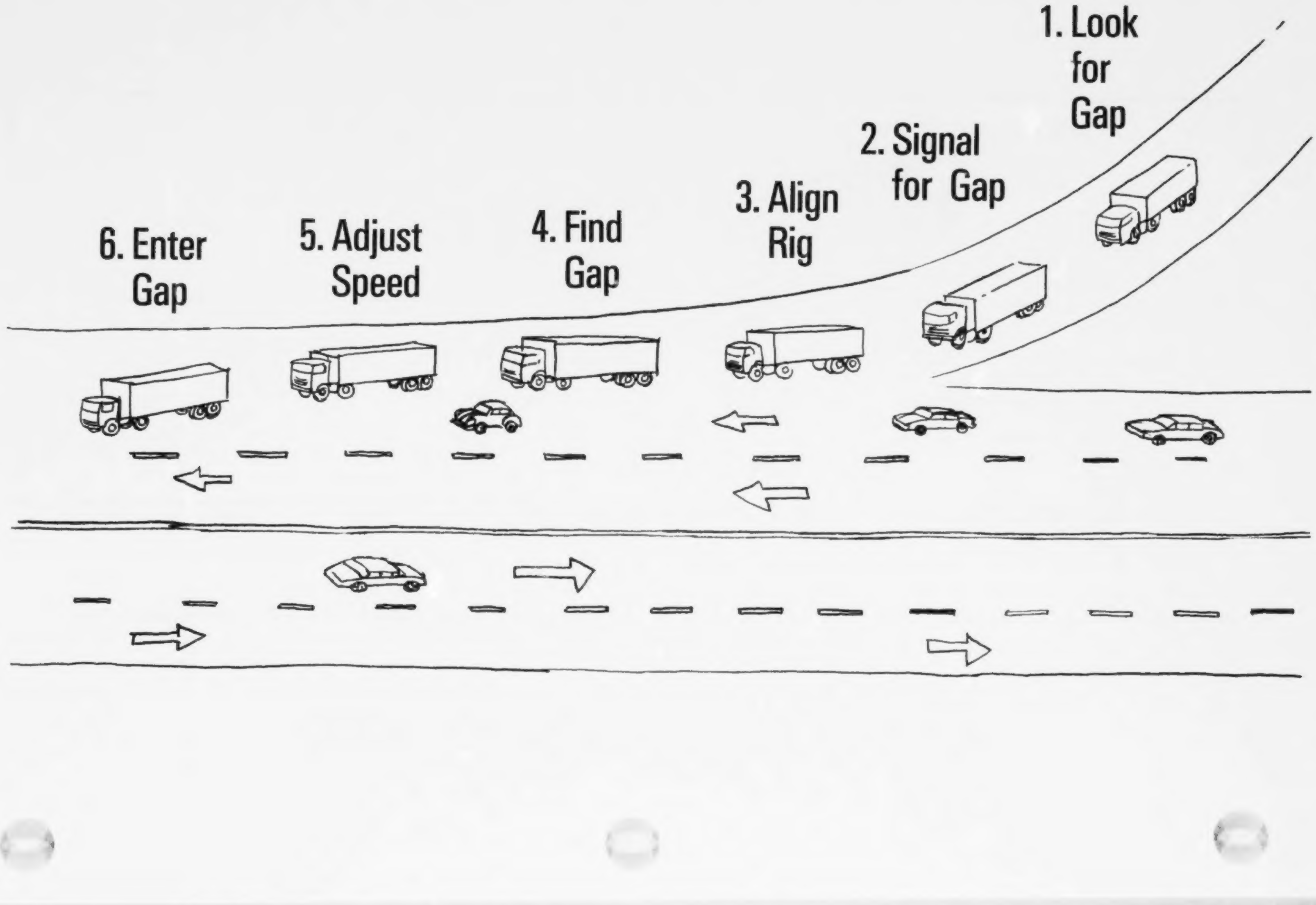
Passing Situation Requiring Two Gaps in Traffic


Oncoming Gap
40 mph = ⅓ mi
30 mph = ½ mi
4 Second Gap Behind
4 Second Gap Ahead

Gaps for Return After Passing



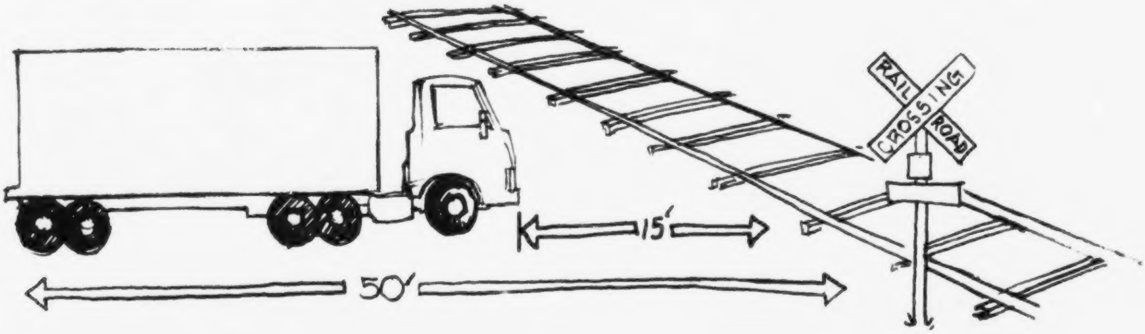
Merging Onto Highway


1. Look for Gap
2. Signal for Gap
3. Align Rig
4. Find Gap
5. Adjust Speed
6. Enter Gap

Visual 20

Railroad Crossing

- Slow Down Even if No Signal
- Stop
  - –When Signal Indicates
  - –When Required by Law
- Give Signal


RAIL ROAD
CROSSING
15'
50'

Right-of-Way—Rules & Situations

Laws Indicate:

- Who Yields Right-of-Way
- Does Not ***Give*** Right-of-Way

Basic Safety Rule:

- Driver With Last Clear Chance to Prevent Accident Does So

Situation	*Rule*
Four-Way Stop	First Stop, First Go
Intersection	Left Yields to Right Turning Vehicle to Straight Vehicle
Emergency Vehicle	Pull Over to Right

Avoid Hindering Traffic

- Multi-Lane Roads
  - Keep to Right
  - Avoid Left Lane
- Upgrades
  - Keep to Right
  - Use Truck Lanes
- Passing
  - Don't Pass:
    - On Hills
    - Other Trucks
- Don't Tailgate
- Being Passed
  - Pull to Right Lane
  - Pull Off Road if Necessary
- Crossing Traffic
  - Make Sure You Can Get All the Way Across
- Other Truck
  - Avoid Packs
  - Don't Double Park

LESSON 2 APPLICATION OF SPACE MANAGEMENT (STREET)

Overview

Time Allotted: 6 hours

Prerequisites: Unit 2.4, Lesson 1

Purpose:

The purpose of this lesson is to provide students an opportunity to practice application of space management techniques and to develop the skills needed in judging space requirements. Students will go out in three person teams per vehicle/instructor. Each student must receive a minimum of 1.75 hours of BTW time.

Materials

Instructional Aids

None

Student Material

Space Management Checklist, in Unit 2.4 of Student Manual
Rules for Onstreet Driving, in Unit 1.1 of Student Manual

Instructor Material

Space Management Checklist (at end of this lesson)

Equipment

Tractor-trailer with a minimum payload of 15,000 pounds
Stopwatch

Content

Activity or Topic	Approximate Time
1. TIMING ACCELERATIONS	1 hour
2. TIMING GAPS	1 hour
3. MANAGING SPACE	4 hours
	6 hours

1. TIMING ACCELERATIONS (1 hour)

This activity involves having students record the length of time required by a rig to cross a stream of traffic, turn and enter a stream of traffic, and pass another vehicle. The three different types of maneuvers may be interspersed.

Purpose

The purpose of this activity is to enable students to determine the amount of time needed to safely (1) cross traffic at an intersection, (2) enter traffic at an intersection, and (3) pass a vehicle ahead.

CROSSING TRAFFIC

Route

The intersections at which accelerations are timed should meet the following conditions:

Entry Street--The street from which the intersection is approached should allow the tractor-trailer to remain at the intersection for up to a minute without interfering with following traffic. Alternative possibilities include:

- a seldom used road or street.
- a driveway or parking lot exit.
- a road at which the truck can be safely pulled to the curb, out of the way of traffic.

Cross Street--Traffic in the cross street should be of relatively low density. Higher densities complicate the exercise and may impede the progress of the vehicle. Posted speed on the selected cross streets should range from approximately 30 to 55 mph to allow practice in dealing with a variety of gap sizes.

Directions

After coming to a stop, the student should be directed to proceed across the intersection. Using a stopwatch (or counting, if necessary,) the instructor should determine the interval between the time the truck begins to move forward and the time the trailer has completely cleared the intersection. The time should be announced to the students and recorded for further reference.

TURNING INTO TRAFFIC

This maneuver may be performed at the same intersections as the preceding maneuver. Instead of proceeding across the intersection, the student will turn right or left as directed. The instructor will determine the interval between the time the truck begins to move and the time it has reached some selected landmark downstream (e.g., cross streets).

PASSING A VEHICLE AHEAD

Route

This exercise should take place on multi-lane highways posted at speeds ranging from 40-55 mph.

Directions

Upon overtaking a slower moving vehicle ahead, the instructor will direct the driver to follow at a safe distance. When the adjacent lane is clear, the instructor will direct the student to change lanes (preferably to the left), pass the vehicle, and return to lane when there is an acceptable gap behind the truck (as determined by the instructor). The instructor will record the interval between the time the truck and trailer have returned to the lane ahead of the vehicle and the time the oncoming vehicle arrives.

2. TIMING GAPS (1 hour)

Directions

The purpose of this activity is to enable students to distinguish acceptable or unacceptable gaps in crossing traffic, entering traffic, and passing a vehicle ahead.

CROSSING TRAFFIC

Route

Same intersections used to time acceleration across traffic in the previous exercise may be used in this exercise.

Procedure

The procedure at each intersection will involve the following:

1. The Instructor picks out a vehicle approaching from either direction and asks the student driver to say now at the last instant that he/she thinks that the truck could safely pull across the street. An equal number of right and left approaching vehicles should be used.

2. Observers are asked to assess the student driver's judgment immediately after the now signal is given.

3. The instructor times the interval from the moment the student says now to the moment the vehicle crosses the truck's path.

4. Instructor compares the time recorded with that required to accelerate the truck across the same or similar intersection.

5. This activity should continue at each location until the driver is correct in two consecutive judgments (or following traffic necessitates moving to another location).

Performance is assessed as follows:

Correct--The gap time is at least 2 seconds and no more than 5 seconds longer than the tractor-trailer's acceleration time recorded earlier. The tractor-trailer could have crossed the street without interfering with the progress of the approaching vehicle.

Too Close--The gap time is less than 2 seconds greater than the acceleration time. Had the tractor-trailer pulled out, it would have infringed upon the right-of-way of the approaching vehicle.

Too Far--The gap time is more than 5 seconds greater than the acceleration time. The tractor-trailer driver would have passed up an acceptable gap. Vehicles behind the truck would have been unnecessarily delayed.

NOTE: Students should be informed that passing up an acceptable gap is certainly correct when a driver is in doubt. However, in this lesson, it indicates lack of skill in estimating gaps. Since this lack of skill could easily produce the opposite kind of error (i.e., accepting an insufficient gap) it is treated as incorrect. Once students have demonstrated that they are able to estimate gaps correctly, their rejection of safe passing opportunities will be considered evidence of caution rather than lack of skill.

The entire exercise should be repeated at a sufficient number of locations to allow each student an opportunity to judge gaps involving vehicles approaching from different directions and at different speeds on streets of differing widths.

ENTERING TRAFFIC

Route

This exercise will be performed at the same locations as used to time accelerations entering traffic in the previous exercise.

Procedure

This exercise would be performed in the same manner as the previous exercise except that the instructor will time the gap between the moment the student says "now" and the time the vehicle reaches the selected landmark. Performance is assessed using the same criteria employed in the previous exercise.

PASSING A VEHICLE AHEAD

Route

This exercise would be performed on a rural 2-lane road with very little traffic.

Directions

The following procedure would be employed in this activity:

1. As an oncoming vehicle approaches, the instructor asks the student driver to say "now" at the last instance that he/she thinks that the truck can safely pull out and pass a (real or imagined) vehicle ahead.
2. Observers are asked to assess the driver's judgment immediately after the "now" signal is given.
3. The instructor times the interval from the moment the students says "now" until the moment the oncoming vehicle passes the truck.
4. The instructor compares the time record with that required to complete a pass in the acceleration activity earlier.
5. This activity should continue until the driver has correctly made two consecutive judgments.

Performances are assessed as follows:

Correct--The gap is at least 2 seconds and no more than 5 seconds longer than the tractor-trailer passing time recorded earlier. The tractor-trailer could have passed the vehicle ahead without interfering with the progress of the oncoming vehicle.

Too close--The gap time is less than 2 seconds greater than the passing time. Had the tractor-trailer attempted to pass, it would have caused the oncoming driver to slow down or put the tractor-trailer driver to cut off the vehicle being passed.

Too far--The gap time is more than 5 seconds greater than the separation time. The tractor-trailer would have passed up an acceptable gap. The vehicles behind the truck would have been unnecessarily delayed.

3. MANAGING SPACE (4 hours)

Purpose

The purpose of this activity is to allow students to apply space management practices within the highway traffic environment.

Route

The route chosen for this lesson should meet the general characteristics, and permit the maneuvers described in Street lessons for Units 1.8 and 2.1. However, greater traffic density is both permitted by the amount of Street operation the student has had prior to this lesson and is needed in order to provide opportunities to apply these space management principles. The driving environment should include urban areas with traffic of moderate density as well as suburban, rural, and expressway driving.

Directions

In addition to the general procedures described in the Introduction, the following procedures should be used during this lesson:

> Following Distance Illustration--At various points along the route, the instructor should direct the driver to practice safe following distances (Timed Interval Driving as specified in Lesson Number 1) in order to illustrate the ability to maintain adequate following distances without having large numbers of vehicles intrude upon the gap.
>
> Clearances--The instructor should not direct students along a route where overhead clearances are inadequate. The student may assume that the instructor would not direct students along routes with inadequate clearances. However, students may be "allowed" to select such routes. For example, the student might be asked to "drive over Main Street" at a point where the nearest available cross street, and the one a person would ordinarly take at that point, will present a clearance problem (e.g., tree limbs). The instructor must be prepared, of course, to prevent actual collisions with any overhead objects.

In order to avoid hazardous situations to instructor and students and to avoid liability to the school, the instructor must intervene whenever the student's action presents a clear and present danger. Specifically, students should be warned if they are:

- About to accept an inadequate gap.
- Entering a lane from which they are prohibited by law.
- In danger of cutting off another vehicle by a premature lane change.
- In danger of placing the vehicle where it will obstruct traffic.
- Continuing to follow closer than permitted by law.

Observations

Students and instructor should observe and record errors in carrying out basic control, search, communication, and space management behavior using the checklists provided. Space management errors are as follows:

Separation

Following Distance--Not allowing the proper number of seconds of following distance for the (combined) vehicle length, and adding to that the required number of seconds for speed (above/below 40 mph) involved.

Lateral Separation--Failure to maintain a center lane position when passing parked vehicles, or being passed by oncoming or overtaking vehicles.

Passing Distance--Changing lanes (returning to right lane) too quickly in front of a vehicle that has been passed.

Overhead Clearance--Having to be stopped by the instructor to prevent collision with an overhead object.

Lane Use

Upgrade--Impeding other traffic by failure to enter the right-most lane on an upgrade.

Multilane Roads--Failure to enter the lane most appropriate to the truck speed and intended maneuver.

Cross Streets--Attempting to traverse or enter a cross street when there is insufficient space to accommodate the tractor-trailer.

Right Turn--Swinging left too far or too early and failing to close off the right side to overtaking traffic.

Left Turn--Swinging right before starting turn, (buttonhook type turn when unnecessary) or cutting diagonally across the intersection.

Multi-lane Turns--Using inside lane where traffic turns in two lanes.

Gaps

Too close--Attempting to cross or enter an insufficient gap.

Too far--Passing up an acceptable opportunity to cross or enter

Merging

Barging-Causing a vehicle to alter speed/direction in order to avoid an accident during a merge attempt.

Stopping--Slowing or stopping when an earlier speed adjustment would have permitted a continuous merge.

Alignment--Not aligning rig parallel to highway for optimum rear vision.

Traffic Adjustments

Compromising--Passing two potential hazards simultaneously when a speed adjustment would have allowed them to be passed in sequence.

Adjacent Operation--Unnecessarily prolonged operation alongside an adjacent vehicle or vehicles.

Notes:

UNIT 2.4 SPACE MANAGEMENT CHECKLIST

If a driver makes a driving error in one of the categories below, place a tally mark in the box.

	DRIVER		
BASIC CONTROL	#1	#2	#3
Acceleration			
Braking			
Stopping			
Upshifting			
Downshifting			
Uphill Operation			
Downhill Operation			
Speed Adjustment/Curves			
Lane-Keeping/Straight			
Lane-Keeping/Turns			
Lane-Keeping/Curves			

	DRIVER		
VISUAL SEARCH	#1	#2	#3
Distance Scanning			
Turn Path Search			
Roadside Scanning			
Blind Intersect., Priv.			
Blind Intersect., Burd.			
Mirror Usage, General			
Mirror Usage, Slowing			
Mirror Usage, Lane Ch.			
Mirror Usage, Merge			
Positioning, Merge			

		DRIVER		
COMMUNICATION		#1	#2	#3
Signaling Turns:	None			
	Late			
	Early			
Lane Changing:	None			
	Late			
	Inappropriate			
	Position			
Canceling:	Late			
	Early			
Flashers				
Brake Lights				
Use of Horn:				
	Insufficient			
	Improper			
Interpreting Communications				
	Receiving			
	Misinterpreting			

	DRIVER		
SPACE MANAGEMENT	#1	#2	#3
Separation			
Following Distance			
Lateral Separation			
Passing Distance			
Overhead Clearance			
Lane Use			
Upgrade			
Multi-lane Roads			
Cross Streets			
Right Turn			
Left Turn			
Multi-lane Turns			
Gaps			
Too Close			
Too Far			
Merging			
Barging			
Stopping			
Alignment			
Traffic Adjustments			
Compromising			
Adjacent Operation			

An explanation of errors is provided on the back.

UNIT 2.4 SPACE MANAGEMENT CHECKLIST

Explanation of Driver Errors on Unit 2.4 Checklist

Separation

Following Distance--not allowing the proper number of seconds in following distance for vehicle length and speed involved.

Lateral Separation--failure to maintain a center lane position when passing parked vehicles, or being passed by oncoming or overtaking vehicles.

Passing Distance--changing lanes (returning to the right lane) too quickly in front of a vehicle that has been passed.

Overhead Clearance--having to be stopped by the instructor to prevent collision with an overhead object.

Lane Use

Upgrade--impeding other traffic by failure to enter the right-most lane on an upgrade.

Multi-lane Roads--failure to enter the lane most appropriate to the truck speed and intended maneuver.

Cross Streets--attempting to traverse or enter a cross street when there is insufficient space to accommodate the tractor-trailer.

Right Turn--swinging left too far or too early and failing to close off the right side to overtaking traffic.

Left Turn--swinging right before starting turn, (buttonhook where unnecessary) or cutting diagonally across the intersection.

Multi-lane Turns--using inside lane where traffic turns in two lan

Gaps

Too close--attempting to cross or enter an insufficient gap.

Too far--passing up an acceptable opportunity to cross or enter traffic.

Merging

Barging--vausing a vehicle to alter speed/direction in order to avoid an accident during a merge attempt.

Stopping--slowing or stopping when an earlier speed adjustment would have permitted a continuous merge.

Alignment--not aligning rig parallel to highway for optimum rear vision.

Traffic Adjustments

Compromising--passing two potential hazards simultaneously when a speed adjustment would have allowed them to be passed in sequence.

Adjacent Operation--unnecessarily prolonged operation alongside an adjacent vehicle or vehicles.

UNIT 2.5
NIGHT OPERATION

UNIT 2.5 NIGHT OPERATION

PURPOSE

The purpose of this unit is to enable students to operate safely at night.

OBJECTIVES

Performance Objectives

Students must

- adjust speed, following distance, and gap selection to nighttime conditions.
- use high beams wherever legally permitted.
- dim headlights in accordance with State laws and to minimize interference with visibility of other drivers.
- respond safely to the glare of other vehicles by averting eyes and by not retaliating.
- use any auxiliary lighting properly.

Knowledge Objectives

Student must know

- the procedures for carrying out the performance objectives.
- the effect of level of illumination on ability to see.
- the value of high beams to nighttime visibility.
- State laws covering use of headlights and auxiliary lights.
- the symptoms and danger of fatigue.
- the effect of headlight glare on visibility of others and its implications for the safety of both drivers.
- the general factors affecting night vision, including interior illumination and use of sunglasses during daytime.

Skill Objective

Student must be able to judge speed, distances, and separation under nighttime conditions.

Attitude Objectives

Students must believe that

- the ability to see clearly diminishes at night.
- no one is immune to the effects of fatigue.

LESSONS

Lesson 1. Night Operation (Classroom)	**45 minutes**
Lesson 2. Night Operation: Basic Maneuvers (Range)	**3 hours**
Lesson 3. Night Operation: Onstreet (Street)	**4 hours 30 minutes**

LESSON 1 NIGHT OPERATION (CLASSROOM)

Overview

Time Allotted: 45 minutes

Prerequisites: Unit 2.4, Lesson 1

Purpose:

The purpose of this lesson is to describe the special problems of night driving and the changes in inspection, search, communication, speed management, and space management needed in dealing with these problems.

Materials

Instructional Aids

Visuals 1 through 6

Student Material

No additional material required.

Instructor Material

Information about sight distances and power of headlights of school training vehicles.

State laws regarding use of headlights at night, i.e., distance at which lights must be dimmed when approaching or following traffic.

Content

Activity or Topic	Approximate Time
1. NIGHT DRIVING FACTORS	20 minutes
2. NIGHT DRIVING PROCEDURES	25 minutes
	45 minutes

1. NIGHT DRIVING FACTORS (20 minutes)

Driving at Night More Dangerous

More than one-half of all traffic accidents occur at night

Most fatal accidents occur between sunset and sunrise
    Less traffic, fewer miles traveled at night
    Significant part of truck miles do occur at night

Why Do So Many Accidents Occur With Less Exposure?

Low illumination makes things harder to see
    Hazards must be much nearer before they can be seen
    Closer distance leaves less itme to respond

Drivers caught by surprise are less able to avoid a collision.

All three elements of highway traffic system are involved in night driving problem
    Driver
    Roadway
    Vehicle

Visual 1 Driver Factors

Driver

Vision

Humans have limited night vision
    Cannot see as sharply (visual acuity)
    Cannot see as well to the sides (peripheral vision)
    Different parts of the eyes used to see at night than during the day
    Need time to adjust to change between light and darkness
Dusk is dangerous time
    Can demonstrate this point by darkening room or by simply pointing out common experience of adjusting eyes to darkened movie theater
Night vision more affected by age than vision during day
    The older the person gets, the more light needed to see at night
Wearing sunglasses during bright days can benefit night vision

Glare

Drivers can be temporarily blinded by glare
Due to physical makeup of eyes it takes time to recover from glare blindness (illustrate by pointing out common experience of being temporarily blinded by flashbulbs)
Rate of recovery from glare varies with individuals
    1/2 second to several seconds or more with intense glare
    Distance traveled in 2-seconds at 55 mph is 160 feet

Fatigue

- Driver fatigue serious factor at night
- Fatigue reduces visual acuity
- Driver become less alert
- Can't see hazards as soon
- Doesn't react as quickly
- Result
  - Less time to react
  - Reflexes are slower
  - Much greater chance of collision

Driver Inexperience

- New car drivers have higher accident rate at night
  - Rates higher than experienced drivers
  - But new drivers drive fewer miles at night

  - What this example shows
    - Takes longer to learn how to adjust driving habits to night conditions
    - Tractor-trailer accident records show similar experience
    - Less driving experience means more accidents at night
    - Ironically newer drivers most likely to get night driving duty

  - What this points to
    - There is a need to learn how to adjust speed, space, driving techniques for night driving conditions

Visual 2 Roadway Factors

Roadway

Traffic Scene at Night is Different Than in the Day

- Some hazards can't be seen at night, i.e., pedestrians, small animals
- All hazards are not seen as quickly at night
- Some hazards are perceived differently

Low Nighttime Illumination

- None on dark rural roads, depend entirely on headlights
- Fair to poor with some street lights

Variation in Illumination

- Need to constantly adjust, e.g, dark on entrance/exit ramps, lighted on highways.
- Flashing neon lights distract as much as illuminate
- Traffic signals hard to see against background of other lights (signs, shop windows, etc.)

Familiarity With Roads

Need to be especially alert on roads that you have never driven in the day

Must fight tendency to be overconfident on familiar roads
  View is not the same at night
  Situation may be different (i.e., stalled car; fallen tree)

Other Road Users

Many vehicle/pedestrian accidents occur at night
Pedestrians, joggers, bicyclists, small animals, hard to see
Animals transfixed by headlights

Drinking Drivers

Nighttime brings out drunks
Be especially alert around closing times at roadside taverns, etc.
Watch for drinking drivers or pedestrians coming out of parking lot.
Continue to be alert for signs of drinking drivers in early hours of morning just after taverns close

Visual 3 Vehicle Factors

Vehicle

Third element in night driving is vehicle

Driver plays important role in making sure vehicle safe for night driving

Headlights

Primary source of light to see and be seen
Field of vision with lights in good working order is much lower than daytime
  Low beams ahead about 250 feet
  High beams ahead about 350-500 feet
Restricted view ahead
Driver should not overdrive lights
  Sight distance limited to range of headlights
  Stopping distance must not exceed sight distances
  Speed must be lowered to reduce stopping distance
  If speed exceeds sight distance, driver is "overdriving headlights"
  (Reference discussion of speed and visibility in Unit 2.3 Speed Management)
Lowered speed is necessary to avoid collision with obstacle coming into view
Reduce speed as necessary to keep stopping distance within sight distance

Headlight Problems

- Headlights view restricted by dirt
  - Clean operative equipment essential for night driving
  - Dirty headlights can severely reduce illumination provided up to 50 percent
  - Also cut down on ability to be seen

- Headlights out of adjustment
  - Do not provide proper field of vision
  - Don't get best view of road
  - Blind other drivers

Auxiliary Lights

When all lights are working, tractor-trailers can be easily seen
- To be easily seen, the following must be clean
  - Reflectors
  - Marker lights
  - Clearance lights
  - Taillights
  - Identification lights
  - Brake lights

- Inoperative or dirty lights
  - Vehicle less visible
  - Can be cause for being pulled off the road

Turn Signals

- To communicate: stop lights and turning signals are vital
  - More important at night than in day
  - Provide only means of communicating intent in many nighttime situations (during day vehicle position and speed, other traffic conditions, etc., can communicate)
  - Inoperative stop lights or turn signals gravely increase accident risk at night
  - Ice and snow covered drastically reduce visibility to others

Windshields

- Clean windshield is must for safe driving
- Even clean windshield cuts out 5 percent of available light
- Dirty windshield restricts light and vision critically
    - Heavy smoking creates a film on inside of windshield
    - Very difficult to see well
    - Best bet is not to smoke
    - Clean periodically with water and cleaning solution
  - Streaky windshield wipers seriously restrict vision at night

Mirrors

Dirty, streaked mirrors also problem at night.

2. NIGHT DRIVING PROCEDURES (25 minutes)

Visual 4 Night Driving Checklist

Preparing to Drive at Night

Getting Yourself Ready

- Dirty or scratched glasses increase glare
- Sunglasses should not be worn at night
- Get eyes checked periodically (especially as you get older)

Plan Your Route

- Know where rest stops are (to aid in fighting fatigue)
- Know the hazards of a particular route
  - Unlighted areas
  - Exit ramps
  - Rural roads
  - Construction areas
  - Taverns
- Get information about unfamiliar routes

Getting the Vehicle Ready

- Perform regular pretrip inspection
- Check all lights
  - Can spot defects not visible in daytime inspection
  - Clean again during stops, particularly if weather is bad
- Replace bulbs; clean lenses and reflectors
- Use flashlight to inspect vehicle

Driving at Night

Visual 5 Night Driving Procedures

Avoiding Blinding Others

- Glare from headlights can be problem
  - In mirrors from following vehicles
  - Directly in eyes from oncoming vehicles
  - Truck driver may underestimate problem due to cab height
- Dim lights before they cause glare for other driver
  - Meeting oncoming vehicle--500 feet
    - Federal Motor Carrier Safety (FMCS) regulation satisfies all State laws as well
  - Overtaking vehicle ahead--200 feet
    - Federal Motor Carrier Safety (FMCS) regulations do not deal with this
    - 200 feet satisfies most State laws

Avoiding Glare From Oncoming Vehicles

- Do not look directly at lights of oncoming vehicles
    - Signal by flicking lights
    - Do not retaliate by using high beams
        - Other drivers could be blinded
        - Greatly increases chance of accident
- Glance to the right to avoid glare

Maximizing Visibility

- Don't let inside of cab get too bright
    - Makes it harder to see outside
    - Dim lights
    - Keep dome light off
- Use high beams
    - Many drivers make mistake of always using low beams
    - Seriously cuts down on ability to see ahead
    - Use high beams when safe and legal to do so
        - Most nighttime accidents result from not being able to see
            - Why penalize yourself by just using low beams?
            - FMCS regulations require use of high beams when not within 500 feet of approaching vehicle
    - Headlights from vehicles ahead can help spot hazards
    - Make maximum use of road signs and reflectors as visual guides

Visual 6 Night Driving Adjustments

Adjusting Basic Driving Techniques

Communicating

- Limited to lights and horns
- Signaling intentions more critical at night
    - Signal a little earlier
    - Signal all stops, slowdowns, direction changes
- Important to signal presence when appropriate
    - Eye contact not possible at night
    - Use horn lightly when necessary
    - Avoid blinding others with lights as way of signaling

Space

- Increase following distance at night by at least 1 second
- Need more time to react
    - Potholes and debris more difficult to detect
    - Hazard of lights glaring into mirror ahead

Speed

- Keep speed within sight distance
- (Review effect of sight distance on speed from Unit 2.3 Speed Management)
- Don't overdrive headlights
- Need time to react to obstacles in road
- Control
    - Unmarked shoulders hard to see at night
    - Driver relies solely on headlights for view of shoulder

  - If overdriving headlights, will end up on shoulders when shape of road changes (curve)
  - Could also lose vehicle control if he tries to adjust too rapidly
- Failing to adjust speed at night will result in not enough time and space to react to hazards

Questions for Discussion

What are some of the other nighttime hazards that we haven't mentioned?

What else do you have to be alert for? (e.g., one light cars, construction areas, detours, small vehicles, etc.)

What experiences have you had when driving at night that illustrate the need to adjust basic driving techniques? (Try to get students to volunteer and discuss instances when they had to stop quickly or turn quickly quickly because they saw a hazard belatedly.)

Have you recognized any bad or good night driving techniques by tractor-trailer operators? Discuss.

Driver Factors

- Vision Limited
- Glare
- Fatigue
- Inexperience

Visual 2

Roadway Factors

- Low Nighttime Illumination
- Variation in Illumination
- Familiarity Wtih Road
- Other Road Users
- Drinking Drivers

Visual 3

Vehicle Factors

- Headlights
- Auxiliary Lights
- Turn Signals
- Windshield and Side Windows
- Rearview Mirrors

Night Driving Checklist

The Driver

- Clean Glasses
- Don't Wear Sunglasses
- Get Eyes Checked
- Be Rested

The Roadway

- Plan Your Route
- Plan Your Rest Stops
- Know Where Nighttime Hazards Are I.E., Ramps, Taverns
- Be Extra Careful on Unfamiliar Roads

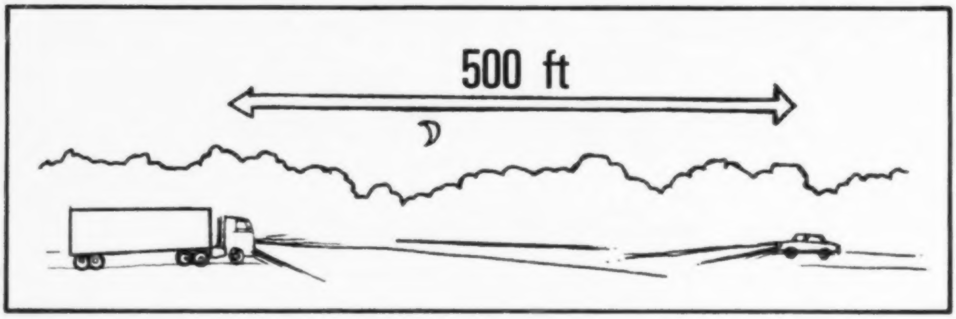
The Vehicle

- Perform Pretrip Inspection
- Check All Lights
- Use Flashlights

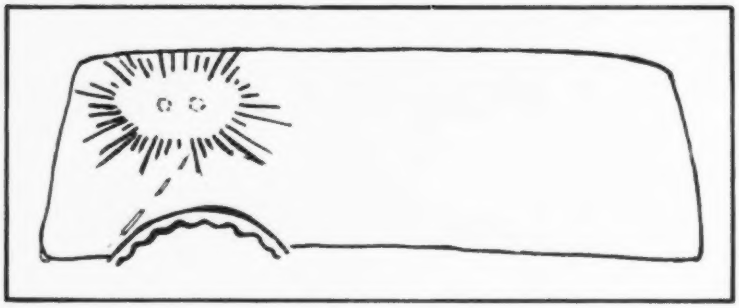
Visual 5

Night Driving Procedures

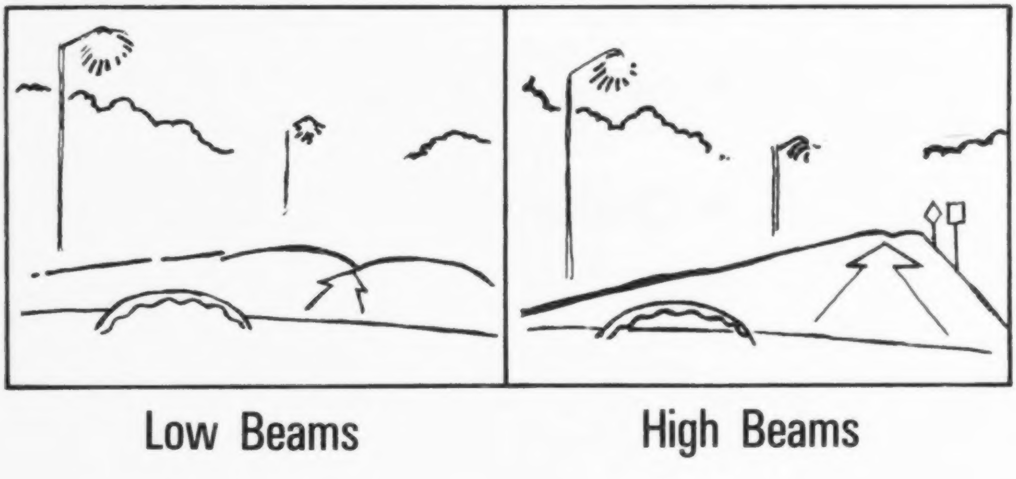
Avoid Blinding Others



Avoid Being Blinded



Maximize Illumination



Low Beams

High Beams

Visual 6

Night Driving Adjustments

Communicating

- Signal Intent Early
- Signal Presence

Following Distance

- More Time to React
- Less Headlight Glare

Speed

- Sight Distance
- Control

LESSON 2 NIGHT OPERATION: BASIC MANEUVERS (RANGE)

Overview

Time Allotted: 3 hours

Prerequisites: Unit 2.5, Lesson 1

Purpose:

The purpose of this lesson is to train students to properly couple/uncouple and inspect a tractor-trailer at night and to gain the ability to judge speed and distance, use lights properly, and handle headlight glare in a protected environment before undertaking nighttime street driving. Each student must receive a minimum of 15 minutes of BTW time in each of the subsection of this lesson for a total of 45 minutes BTW time per student for this lesson.

Materials

Instructional Aids

None

Student Material

Pretrip Inspections Checklist, in Unit 1.3 of Student Manual

Coupling and Uncoupling Procedures Checklists, in Unit 1.7 of Student Manual

Range Safety Rules, in Unit 1.1 of Student Manual

Instructor Material

Pretrip Inspection Checklist, from Unit 1.3

Coupling and Uncoupling Procedures Checklists, from Unit 1.7

Equipment

Tractor-trailer for each team of 3 students

Wiping rags and flashlight for each team

Facilities

This lesson should be conducted in a protected area such as:

> An offstreet driving range on private property, preferable with a roadway around its perimeter where vehicles can meet and pass each other while traveling in opposite directions

A less desirable alternative, is a two-way street that has no traffic or else can be blocked off to traffic during this exercise - in any case safety is the main consideration and steps must be taken to insure that risks of an accident are controlled

Content

Activity or Topic	Approximate Time
1. COUPLING, PRETRIP INSPECTION AND UNCOUPLING	60 minutes
2. MANEUVERING	60 minutes
3. BACKING	60 minutes
	3 hours

1. COUPLING, PRETRIP INSPECTION AND UNCOUPLING (60 minutes)

Purpose

The purpose of this exercise is to give students the experience in coupling and uncoupling a trailer and conducting a pretrip inspection under nighttime conditions.

Range Layout

This portion of the lesson should be conducted in an unilluminated offstreet area. If the area selected is normally illuminated, the lights should be turned out.

Directions

1. Students will work in their usual three person teams, per vehicle/instructor.

2. Students should then couple tractor to assigned trailer.

NOTE: The instructor should check vehicle alignment before students are allowed to back.

3. The students should take turns carrying out the inspection with the aid of a flashlight.

4. The instructor should monitor the inspection to make sure it is being carried out safely and correctly.

5. The instructor should make sure that the student carries out all night-specific checks, including:

   - Mirrors, windshields, and headlights for cleanliness.

   - All tractor and trailer lights for cleanliness and burnt-out bulbs.

6. The student should then uncouple tractor from the trailer.

Observation

The instructor will observe to see if the procedures used are the same as those for pretrip inspection, as described in Unit 1.2.

Evaluation

Not applicable.

2. MANEUVERING (60 minutes)

Purpose

The purpose of this activity is to allow students an opportunity to practice handling the vehicle and dealing with other traffic in a protected environment before beginning nighttime street operation.

Layout

This exercise may be carried out on either an offstreet or onstreet area as follows:

Offstreet Area--This is the best option from the viewpoint of safety and student confidence. The area should be sufficiently large to allow two vehicles to operate at the same time at speeds of 25 mph or greater. If possible, there should be a "road" delineated by paint stripe or pavement edge. Lacking this, cones may be used to designate paths.

Street--If a suitable offstreet area is not available, this exercise may be conducted on a road, two lanes or greater, provided there is little or no other traffic.

Directions

This exercise consists of three sets of maneuvers.

Lane Keeping (20 minutes)

1. Working in their usual three person teams per vehicle/instructor students will operate about the range/road well separated from one another.
2. All vehicles proceed in the same direction in order to minimize headlight glare.
3. Drivers attempt to maintain a stable, suitable lane position.
4. Two other students ride as observers to get used to nighttime operation.
5. Students alternate between high and low beams in order to compare relative visibility.
6. The instructor is only required to give directions. No instruction is necessary.

Interacting with Traffic (20 Minutes)

1. The instructor in each vehicle guides the vehicle along a path that necessitates (1) following the vehicle ahead, (2) crossing the path of intersecting vehicles, and (3) meeting other vehicles head-on.

2. Student observers should comment upon any observed deficiencies in following distance and intervehicle separation.

3. The instructor should make sure that students maintain prescribed speeds.

4. Students operate with high beams except when meeting or following another vehicle.

Handling Glare (20 Minutes)

1. Students are instructed to operate with high beams on.

2. The instructor directs the vehicle along the path that assures meeting other vehicles.

3. If operating onstreet, lights must be dimmed for any nontraining vehicles.

Observation

The instructor will observe for failure to perform the following procedures properly:

In carrying out the exercise, students will employ the following night driving procedures (except where otherwise directed):

- o Lower head lights when meeting or following another vehicle.
- o Maintain at least a 6-second following distance.
- o Use the right edge of the road as a guide when meeting a vehicle with high beams on.

The instructor will watch for the following common problems:

1. Students allowing their speed to drop.

2. Drivers "giving way" to passing vehicles (excessive lateral separation).

3. Drivers not knowing whether their lights are on high or low beam.

3. BACKING (60 minutes)

Purpose

The purpose of this activity is to allow students to practice backing under conditions of low illumination.

Layout

This exercise should be performed in an offstreet area. An alley dock layout may be set up according to the same dimensions as prescribed in Unit 1.8. The alley dock should be delineated by clearly visible markers, e.g., cones or bright striping. One alley dock area should be set up for each vehicle.

Directions

1. Working in their usual three person team per vehicle/instructor, students should take turns backing into and pulling out of the alley dock area to give students the experience of having to back into a dark warehouse from the street during daytime.
2. The instructor and observer students should remain outside the truck on the driver's side.
3. The instructor should interrupt the driver's performance when the vehicle's position at the outset or at any point during the backing maneuver becomes "hopeless".
4. Instructor should point out to the observer students the cause of driver difficulties.
5. If, after each student has had one opportunity, there is time remaining, the student(s) having the greatest difficulty should be given additional practice.

Observation

The instructor will observe for failure to perform the following procedures properly:

Students should use the same backing procedure as employed in Unit 1.6, except that 4-way flashers should be employed to serve as back-up lights.

The instructor should watch for the same common problems as in Unit 1.6.

The instructional observations described in Unit 1.6 are applicable to this exercise as well.

Evaluation

Student performance will be evaluated according to the same criteria as are employed in carrying out the alley dock maneuver in Unit 1.8.

LESSON 3 NIGHT OPERATION: ONSTREET (STREET)

Overview

Time Allotted: 4 hours 30 minutes

Prerequisities: Unit 2.4; Unit 2.5, Lesson 2

Purpose:

The purpose of this lesson is to provide students with instruction and practice basic vehicle control onstreet, under nighttime conditions. Students will go out in their usual three person teams per vehicle/instructor. Each student must receive a minimum of 30 minutes of BTW time in each of the three subsections of this lesson for a total of 90 minutes of BTW time per student.

Materials

Instructional Aids

None

Student Material

Night Operations Checklist, in Unit 2.5 Of Student Manual

Rules for Onstreet Driving, in Unit 1.1 of Student Manual

Driver's Duty Status Record (Driver's Daily Logbook) to record driving time/miles.

Driver's license or learner's permit, as required in your State.

Instructor Material

Night Operations Checklist (at end of this lesson)

Clipboard and several extra copies of the Night Operations Checklist

Equipment

Three small flashlights or pencil lights equipped with red lense covers to use for illuminating checklists for marking without creating a windshield glare to reduce driver's vision

Spare batteries for above

Content

Activity or Topic	Approximate Time
1. HIGHWAY DRIVING	90 minutes
2. RURAL DRIVING	90 minutes
3. CITY DRIVING	90 minutes
	4 hours 30 minutes

1. HIGHWAY DRIVING (90 minutes)

Purpose

The purpose of this activity is to allow students to become accustomed to night driving in a relatively uncomplicated and nonthreatening onstreet environment.

Route

The route should be a suburban or rural highway having the following characterisitcs:

- Limited amount of traffic
- Wide lanes
- Clearly discernible lane and edge delineators
- Uncontrolled intersections requiring entering or crossing traffic

A large divided highway or freeway is suitable for this activity.

Directions

In addition to the procedures described in the Introduction, the following steps will be taken:

1. Students should be instructed relative to speed and position in order to create overtaking and passing situations.

2. As important roadway configurations, road signs, and other important road conditions are approached, students should be instructed to dim the headlights in order that the effect of low beams in reducing visibilty can be observed.

3. Instructor and observer students should be careful not to allow flashlights to cause glare, in cab while marking checklists.

Observations

The student and instructor should observe and record errors in carrying out basic control, search, communication, space management, and night driving behaviors using the checklists provided. Nighttime driving errors are as follows:

Lights High Beam--Failure to return the lights to high beam after passing or overtaking another vehicle.

Lights Dimming--Failure to dim headlights according to law meeting or overtaking another road user.

Speed Adjustment--Failure to reduce speed at night where required because of lowered visibility.

Following Distance--Failure to increase following distance to compensate for reduced nighttime visibility.

Gap Selection--Acceptance of an insufficient gap when entering or crossing traffic where it can be attributed to reduced nighttime visibility.

2. RURAL DRIVING (90 minutes)

Purpose

The purpose of this activity is to allow students to practice lanekeeping within narrow lanes, with poorly delineated road edges and in the presence of oncoming vehicle headlight glare.

Route

This activity should take place on rural highways having the following characteristics:

- Two-lane roads
- Narrow lanes
- Undelineated road edges
- Lack of street lighting

Directions

Same as Highway Driving

Observations

Same as Highway Driving. However, instructor will watch specifically for lanekeeping errors resulting from route characteristics, including:

1. Drivers encroaching upon the left lane to avoid the right road edge.

2. Right wheels dropping off the paved surface when meeting an oncoming vehicle.

3. CITY DRIVING (90 minutes)

Purpose

The purpose of this activity is to provide students an opportunity to practice tight maneuvers under nighttime conditions in the presence of intense background lighting.

Route

This activity should take place in an urban area having the following characteristics:

- Parked vehicles restricting width of travel lanes
- Right and left turns at intersections
- High level of background lighting (store windows, signs, headlights of oncoming vehicles)

Directions

Same as Highway Driving.

Observations

Same as Highway Driving.

Notes:

UNIT 2.5 NIGHT OPERATIONS CHECKLIST

If a driver makes a driving error in one of the categories below, place a tally mark in the box.

	DRIVER		
BASIC CONTROL	#1	#2	#3
Acceleration			
Braking			
Stopping			
Upshifting			
Downshifting			
Uphill Operation			
Downhill Operation			
Speed Adjustment/Curves			
Lane-Keeping/Straight			
Lane-Keeping/Turns			
Lane-Keeping/Curves			

	DRIVER		
VISUAL SEARCH	#1	#2	#3
Distance Scanning			
Turn Path Search			
Roadside Scanning			
Blind Intersect., Priv.			
Blind Intersect., Burd.			
Mirror Usage, General			
Mirror Usage, Slowing			
Mirror Usage, Lane Ch.			
Mirror Usage, Merge			
Positioning, Merge			

	DRIVER		
COMMUNICATION	#1	#2	#3
Signaling Turns: None			
Late			
Early			
Lane Changing: None			
Late			
Inappropriate			
Position			
Canceling: Late			
Early			
Flashers			
Brake Lights			
Use of Horn: Insufficient			
Improper			
Interpreting Communications Receiving			
Misinterpreting			

	DRIVER		
SPACE MANAGEMENT	#1	#2	#3
Separation Following Distance			
Lateral Separation			
Passing Distance			
Overhead Clearance			
Lane Use Upgrade			
Multi-lane Roads			
Cross Streets			
Right Turn			
Left Turn			
Multi-lane Turns			
Gaps Too Close			
Too Far			
Merging Barging			
Stopping			
Alignment			
Traffic Adjustments Compromising			
Adjacent Operation			

	DRIVER		
NIGHT OPERATION	#1	#2	#3
Lights/High Beam			
Lights/Dimming			
Speed Adjustment			
Following Distance			
Gap Selection			

An explanation of errors is provided on the back.

Explanation of Driver Errors on Unit 2.5 Checklist

Lights High Beam--Failure to return the lights to high beam after passing or overtaking another vehicle.

Lights Dimming--Failure to dim headlights according to law meeting or overtaking another road user.

Speed Adjustment--Failure to reduce speed at night where required because of lowered visibility.

Following Distance--Failure to increase following distance to compensate for reduced nighttime visibility.

Gap Selection--Acceptance of an insufficient gap when entering or crossing traffic where it can be attributed to reduced nighttime visibility.

UNIT 2.6
EXTREME DRIVING CONDITIONS

UNIT 2.6 EXTREME DRIVING CONDITIONS

PURPOSE

The purpose of this unit is to enable students to operate their vehicle safely under extreme driving conditions such as adverse weather, mountain and desert driving.

OBJECTIVES

Performance Objectives: Adverse Weather

Students must

- prepare for operation in cold weather including proper use of the front brake limiting valve; removing snow and ice from windows, mirrors, brakes, lights, hand and toe holds, etc.; and installing tire chains when necessary.
- inspect for cold weather operation by paying special attention to coolant level and mixture, heater, defrosters, wipers, washers, tire tread, brakes, lights, reflectors, wiring system, hoses, fuel, exhaust system and fifth wheel.
- provide adverse weather equipment including chains, scraper, shovel and warm clothing.
- make sure that moisture is expelled from the air tanks after each trip.
- obtain weather information before and during trips and adjust trip plan accordingly.
- check for ice accumulation on brakes, slack adjuster, air hoses, electrical wiring and radiator shutters during operation.
- adjust operation of vehicle to weather conditions, including speed selection, braking, direction changes and following distance, to maintain control and avoid jackknifing.
- assure safe operation of brakes after driving through deep water.
- use windshield wipers, washers and defrosters to maintain visibility.
- observe road surface for changes in conditions.

Students must be able to

- o start engine in cold weather.
- o mount and dismount tire chains.
- o extricate the vehicle from snow, sand and mud by maneuvering or towing.

Knowledge Objectives: Adverse Weather

Students must know

- o the conditions that produce low traction including initial rainfall, ice, snow and mud.
- o the effects of rain, snow and ice upon the ability to maneuver and stop the vehicle.
- o causes and procedures for avoiding skidding and jackknifing.
- o the nature of hydroplaning and the road and vehicle conditions that produce it.
- o the effect of ice, snow, water, mud, snow and debris on operation of the brakes.
- o the need to make sure all wheels are free to turn.

Skill Objectives: Adverse Weather

Students must be able to

- o adjust rate of change in speed and direction to road conditions to avoid skidding.
- o coordinate acceleration and shifting to overcome the resistance of snow, sand, and mud.

Attitude Objectives: Adverse Weather

Students must believe that

- o adverse weather conditions require special driving techniques.
- o bad weather accidents and jackknifing can be prevented by proper driving techniques.
- o it is necessary to carry special equipment and personal gear to provide for safety during adverse weather operation.
- o it is dangerous for the driver to leave the vehicle in the event of a breakdown during extremely adverse weather conditions.

Performance Objectives: Hot Weather

The student must

- o check tires, lubrication, levels and operation of cooling system, fan belts, fans and hoses, and see the radiator is clear of debris.
- o carry an ample supply of drinking water.
- o inspect tires frequently.
- o avoid leaving the vehicle if it is disabled in the desert.

Knowledge Objectives: Hot Weather

The student must know

- o procedures for hot weather driving.
- o the hazards of hot weather driving.
- o the effect of hot weather upon the vehicle operation.
- o the effect of hot weather upon tire pressure and tire life.

Skill Objectives: Hot Weather

No new objectives

Attitude Objectives: Hot Weather

The students must believe that

- o hot weather can impede vehicle operation.
- o special precautions are required in inspecting the vehicle and preparing it for hot weather operation.
- o it is dangerous to leave a vehicle when it is disabled in the desert.

Performance Objectives: Mountains

Students must

- o check brake adjustment prior to mountain driving.
- o use right lane or special truck lane going up grades.
- o place transmission in appropriate gear for engine braking before starting down grade.
- o use proper braking techniques and maintain proper engine speed on long downgrades.

- properly use special speed reduction devices (e.g., engine exhaust brakes).
- use truck escape ramp if available when brakes fail on a downgrade.
- observe temperature gauge frequently when pulling heavy loads up long grades.

Knowledge Objectives: Mountains

Students must know

- the effect of vehicle weight and speed upon braking and shifting ability on long downgrades.
- the function and value of escape ramps.
- the meaning and use of percent of grade signs.

Skill Objectives: Mountains

- use proper downhill gearing.
- operate braking systems for maximum efficiency and safety.

Attitude Objectives: Mountains

Students must believe that

- the weight of the tractor-trailer vehicle and load poses hazards in long downgrades unless the truck is put into proper gear at the right time.
- attempting to downshift on steep decline is too dangerous to attempt
- use of a truck escape ramp is safer than attempting to negotiate a downgrade when the vehicle is out of control.

LESSONS

Lesson 1.	**Operation During Extreme Driving Conditions (Classroom)**	**3 hours 15 minutes**
Lesson 2.	**Techniques Used During Extreme Conditions (Range)**	**4 hours**

LESSON 1 OPERATION DURING EXTREME DRIVING CONDITIONS (CLASSROOM)

Overview

Time Allotted: 3 hours 15 minutes

Prerequisites: Units 2.5, Lesson 1

Purpose:

The purpose of this lesson is to point out and briefly discuss the operating procedures and hazards associated with extreme driving conditions. Adverse weather, hot weather, and mountain driving will be discussed.

Materials

Instructional Aids

Visuals 1 - 11

Student Material

Adverse Conditions Inspection Checklist, in Unit 2.6 of Student Manual

Instructor Material

No additional material required

Content

Activity or Topic	Approximate Time
1. ADVERSE WEATHER	1 hour 40 minutes
2. HOT WEATHER	20 minutes
3. MOUNTAIN DRIVING	1 hour
4. SUMMARY	15 minutes
	3 hours 15 minutes

READEX FICHE

1. ADVERSE WEATHER (1 hour 40 minutes)

Driver awareness and knowledge of his vehicle's components, systems, and operating procedures are important in normal driving

They are critical when operating in extreme driving conditions

- Because of reduced traction
  - Stopping distances are greater
  - Maneuverability and control are decreased
- Because of reduced visibility
  - Can't see hazards as soon
  - Reduce time to respond

Visual 1 Driver Checklist

Adverse Weather Vehicle Checks

A driver must make sure his vehicle as well as himself are prepared before driving in winter weather
Driver should make regular pretrip inspection, paying particular attention to the following items

Coolant Level and Antifreeze Concentration

- Check with tester (see vehicle or company specifications)
- Make sure cooling system is full
- Low coolant level effects how well heater/defroster works

Heating Equipment

- Cab heating
  - Check heater hoses
  - Make sure coolant from engine can reach heater
  - Controls and fans should be working
  - Become familiar with the controls
    - No two makes entirely alike
  - Read operators manual
- Window defrosters
- Auxiliary heaters
  - Mirror heaters
  - Battery box heaters
  - Fuel tank heaters

Wipers/Washers

- Check washer reservoir
  - Look for cracks, collapsed areas, loose clamps
  - Make sure its full, and not frozen
  - Needs antifreeze to function in winter
- Make sure washer works

- Test wiper assembly
  - Blade rubber in good condition
  - Operating at manufacturers recommended arm pressure
  - Should sweep snow off not slide over it

Tires

- Check tread depth
  - Particularly important on drive wheels
  - Must provide enough traction to push rig over wet pavement, through snow
- Check mounting
- Check air pressure
- Inflate to recommended pressure for winter driving
- (See tire specifications in Owner's Manual)

Chains

- Prepare for the worst
- Carry appropriate number of chains and extra cross links
- Make sure they will fit your truck tires
- Check for
  - Broken hooks
  - Worn or broken cross links
  - Bent or broken side chains
- Determine if chain slack adjustors are available (if needed)

NOTE: Tire chains will be covered in greater detail later in lesson

Brakes

- Have balance checked
  - Rear axle should get air first
  - Brakes should apply in sequence from rear to forward axle
- Check adjustment
  - Take up slack
- Actuate front brake limiting valve (when applicable)
  - Hand switch in cab
  - Limits air pressure to brake chambers
  - Helps prevent front wheel lock up
- Check for ice on brake linings
  - Can reduce braking power
  - Can cause shoes to freeze to drum when stopped
- Drain moisture from air tanks
  - Both tractor and trailer tanks
  - Moisture in air lines will cause brakes to freeze
  - Check moisture control equipment in very cold weather (if provided)
    - Moisture ejection equipment (e.g., spitter valves)
    - Alcohol evaporators

Lights and Reflectors

- Wipe clear any dirt, mud, salt, ice, snow, etc.
- Stop, tail, clearance, side and directional lights must work and be clean
- Check during trip in bad weather

Windows, Mirrors, and Reflectors

- Before starting remove ice, snow, etc. from windshield, windows, mirrors, and reflectors
- Scrape, brush and use defroster

Hand and Toe Holds

- Remove all ice and snow
  - Creates dangerous situation for driver entering and leaving cab

Radiator Shutters and Winterfront

- Remove ice from shutters
- Ice prevents shutters from opening, causing engine overheating
- Watch engine temperature during operation
- Adjust shutters winterfront to maintain normal temperature
  - Close if too cold
  - Open if too hot

  - Causes
    - Engine to over heat
    - Engine damage
- Opening and closing at proper temperature (usually about 185°F)

Exposed Wiring and Air Lines

- Remove ice and snow
- Make sure they are properly supported
  - Snow and ice buildup can cause lines to sag
    - Can snag in tire chains

Fuel Tank

- Make sure tank is full before starting
- If bad weather is expected, top off tank frequently, in case you are stranded for a long period of time

- Keep water out of fuel
  - A problem with low quality fuel
  - Can freeze in fuel lines and filters
  - Precautions
    - Fill tank at end of trip to reduce moisture build up
    - Drain water from bottom of fuel tanks

Engine and Exhaust System

- Exhaust connections must be tight
- If not carbon monoxide can lead into vehicle

Coupling Devices

- Double check, locking mechanism
- Make sure it's lubricated on fifth wheel (winter grade lubricant)
  - Prevents binding
  - Helps steering on slippery roads

Interaxle Differential Lock (If so equipped)

- Check for proper operation
- Check for moisture in air lines (if air operated)
- Check operator's manual for proper operation

Emergency Gear

Emergency Equipment

- Windsheld scraper
- Snow brush
- Shovel (small shovel, folding handle, army surplus sufficient)

Driver's Personal Gear

- Drinking water
- Extra food
- Medicine (when necessary)
- Hats, boots, and gloves
- Extra pair pants (in case the ones being worn get wet)
- Proper outerwear

Driving in winter weather without proper equipment and clothing can be deadly

Weather Reports--Road Conditions

- Drivers should keep themselves informed of latest weather and road conditions
- National Weather Radio Service broadcasts constantly updated weather forecasts (162.40 - 162.55r MHz) from many locations around country
- Very important, especially in volatile areas, i.e., western mountainous states
- Plan your trip accordingly

Visual 2 Tire Chains

Tire Chains

Construction

- Cross chains
  - Portion of chains that go across the tire
  - Provide traction

- Side chains
  - Portion of the chains that go around the tire
  - Hold the cross chains

Links

- Conventional links--ordinary chain links
- Reinforced--V-lugs or cleats welded to cross chain to improve grip

Types

- Single--goes over single tire (outside tire in a set of duals)
- Double--goes over a complete set of duals

Importance

- A must for winter driving in many areas
- Difference between going and not going
- Increases traction up to 500 percent
  - Drive wheels--improve pulling power going uphill
- Trailer wheels--improve braking going downhill
- Helps avoid stalling, skidding, and jackknifing
  - Important to mount chains at first sign of slippery conditions
- Risky to proceed without chains
  - Could get stuck and be unable to proceed
  - Could slide off road and sustain damage

Requirements

- Many mountainous States have specific requirements for chain use under varying weather conditions
- See individual State requirements
- Drivers should know requirements for States they operate in

Location

- Again requirements will vary from State to State
- In western States, location requirements may vary from highway district to highway district
- Be aware of regulations

EXAMPLES: chain location
- 18 wheel, 5-axle, tractor-trailer
  - Twin screw
    - Front drive axle - outside dual wheels only
    - Rear drive axle
      - Inner and outer duals
      - Both sides of tractor
  - Trailer
    - Rear axle - outside dual wheels

- 18 wheel, 5-axle, doubles
  - Single drive
    - Drive axle - inside and outside duals

  - Trailers
    - Outside duals
    - Front and rear trailers
    - Rear axles
  - Converter gear
    - Outside duals
- When operating on steep up or downgrades, chains are needed on:
  - Upgrades--Drive axle(s)
  - Downgrades--Rear trailer axle(s)

Chain Control Area

- Highway areas (under certain road conditions) where its illegal to run without chains

Screening

- Stations usually set up ahead of chain control areas
- Trucks are stopped, check for proper number of chains
- If necessary chains are not on-board, vehicle will not be allowed in chain control area
- Prepare your vehicle for the worst possible conditions

Speed Limit

- Maximum speed with chains - 30 miles per hour unless posted

Use

- Most effective
  - Heavy wet snow
  - Freezing rain
    - Heavy ice accumulation or ice on top of snow
    - Need reinforced chains; conventional chains are no help
    - Ice or snow is "slipperiest" at freezing level (32°F or 0°C)
- Light dry snow
  - Not much traction advantage
  - Does add to stability
- Most chains not effective on glare ice

Installation

- Don't be afraid of chain installation
- Once procedure is mastered, process is relatively easy
- Chains should be snug, not tight
- They are designed to creep or move on the tires (prevents gouging)
- They should be retightened after driving 5 miles to prevent slap against trailer or catching on suspension

- Precautions
  - When outside vehicle, installing chains, exercise extreme caution
    - Vehicles running on snow are quiet even with chains
    - New snowfall absorbs sound
    - Hot tires melt snow
      - Causes surface to become very slippery
      - Vehicle may slide sideways while parked
    - Drivers may
      - Not see you
      - Apply brakes and slide into you

Drivers putting on chains should
- Pull well off road
- Park on level service
- Work facing traffic
- Know where to go if confronted with an out-of-control vehicle
- Watch footing
- Watch your own rig (sometimes vehicles with hot tires will slide on slippery surfaces)

NOTE: A step-by-step procedure of chain installation will be covered in Lesson 2.

Visual 3 Cold Weather Starting Aids

Cold Weather Starting

Available Aids and Starting Procedures

Starting Fluids

Ether or Ether Based Fluid
- Very low flash point (ignites easily even at subzero temperatures)
- Extremely high energy fuel
  - Will damage engine if used improperly or too frequently
    - Crack cylinder heads
    - Break pistons
    - Snap rods
- Highly flammable
  - Avoid smoking while using
- If spilled on clothing, change clothes

Various Forms
- Capsules (jelly beans)
- Aerosol spray cans
- Pressurized cylinders
- Driver controlled injection systems

Application
- Can be administered manually or automatically
- Manually
  - Capsules
    - Each capsule provides one start
    - Requires just one individual to start the engine
    - Place in special receptacle attached to air cleaner
      - Do not put in air cleaner itself
      - Can get sucked into engine and cause damage
- Aerosol spray cans/pressurized cylinders
  - Requires two persons
    - One spraying ether into rag hung in front of air cleaner
    - Second to start vehicle
  - Does not take much--over spraying may result in
    - Flash back
    - Engine damage

- Automatically
  - Injection systems
    - Requires only the driver
    - Pump meters predetermined amount into intake manifold
    - Done by cab-mounted switch or automatically when tractor started
    - Eliminates excessive ether doses that cause engine damage

Glow Plugs

Electric Heating Element

- Warms air coming into engine from air intake
- Warm air needed for fuel to ignite

Location

- Direct injection (Cummins, Mack)
- Mounted in intake manifold
- Precombustion chamber diesels (caterpillar)
- Mounted in each precombustion chamber

Operation

- Consult operators manual for operating instructions
- May include hand priming pump to spray fuel into the combustion chamber
  - Driver must know how to operate
- Increases combustion chamber temperatures
- Hot compressed air ignites fuel
- Usually takes 60 seconds for glow plugs to heat air sufficiently

Caution: Never use ether and glow plugs at the same time
Check for instruction on instrument panel of how to activate glow plug system

Preheaters

- Keep engine warm while vehicle is parked for night
- Most onhighway tractors use "In-block" type
- The other type, "Immersion" used extensively on offhighway construction and mining equipment
- In-block
  - Location--fits into freeze plug holes in lower water jacket
  - Operation
    - Plugs into either 210 or 110 electrical current
    - Coolant heated to approximately 160° (near normal temperature)
    - Circulates throughout engine keeping it warm
    - Eliminates warmup
    - Use normal starting procedures

In extremely cold areas, coolant heaters are frequently supplemented with battery box heaters, oil sump heaters and fuel heaters

Check with maintenance personnel for proper operation
Do not attempt to use without instruction

Nonstarting Engine

If engine doesn't start with use of starting aids, check fuel and electrical system.

Fuel

- Check exhaust stack while cranking engine
- If no vapor or smoke
  - Engine not getting fuel
  - Continued cranking will just run down the battery
- Check fuel tank and lines for blockage by ice
- Check fuel tank vent

Electrical Starters

- Battery does not operate at full efficiency in cold weather
- Must be in best possible condition
- Check for
  - Corrosion on terminals
  - Loose connections
  - Cracks in cables
  - Moisture on cables

Air Starter

- If air supply is exhausted, engine won't start
- Need to resupply air
  - From another tractor
  - From an air compressor
- Check operator's manual on procedures for air resupply

Adverse Weather Operating Hazards

NOTE: The effect of foul weather on safety of operation were introduced in Unit 2.3 Speed Management. This section should provide a brief review.

Visual 4 Primary Hazards

Two Primary Hazards

- Reduced visibility
- Reduced traction

Reduced Visibility

- Vehicle condition
  - In inclement weather, ice and snow tend to build up on windows and mirrors
    - Will reduce visibility: side and rear
    - When this happens
      - Driver must stop frequently and clean off side windows and rearview mirrors
      - Do not attempt to drive with side and rearviews blocked
  - Ice, snow, mud buildup on lights, reflectors also reduce your visibility to other drivers
  - Clean frequently

Reduced Sight Distance

- Adjust speed in bad weather for visibility ahead discussed in Unit 2.3 Speed Management)
- Fog, rain and medium snow fall can cut visibility to 100 feet
- Safe speed for 100 foot stopping distance is 20 mph

Inability to See

- Weather can cut visibility to near zero (particularly at night)
  - Blinding snow
  - Heavy downpour
  - Dense fog
- When this happens
  - Unsafe to drive at all
  - Pull off road and stop
  - Wait until visibility improves before continuing

Reduced Traction

Road surface

- Different surfaces--different degrees of friction (affects traction)
  - Dry concrete--more traction than dry asphalt
  - Wet concrete--more traction than wet asphalt
  - Snow packed or ice covered surface--only 20 percent of traction of wet concrete or asphalt
- Drive wheels spin easily on slippery surfaces
- Spinning drive wheels have no cornering ability
- Greatly impairs maneuverability
- Proper tire tread and weight on drive wheels
  - Enhances vehicle traction
  - Improves maneuverability
- Be alert to changing conditions--make periodic brake applications (when safe) to check traction

Speed

- Ability to control the vehicle decreases as speed increases
  - Traction needed for accelerating, turning, and braking
  - As speed increases, more traction is needed to perform these maneuvers
  - When traction is poor, speed must be reduced to permit maneuvers to be made within available traction
- Determine maximum speed at which control can be maintained
  - Wet surface - reduce speed by one-fourth below normal (posted) speed
  - Packed snow -reduce speed by one-half from normal speed
  - Icy surface - reduce speed by two-thirds from normal speed

NOTE: The above is a general guide. Exact speeds will vary with circumstances (weight and type of truck, type of road surface).

EXAMPLE: Safe dry speed - 55 mph
Rain - 40 mph
Snow - 30 mph
Ice - 20 mph (usually less)

Black Ice

- Ice that is camouflaged by road
  - Ice is clear and cannot be seen
  - Road visible beneath the ice (therefore "black" ice)
- Invisible to driver
- Usually found
  - On bridges
  - Beneath underpasses
  - Dips in road (where melting water collects)
  - Shaded areas
  - Lower sides of banked curves
- Very dangerous when driver not aware or prepared
  - Particularly hazardous at night when it is difficult to spot
  - Unit 3.1 Hazard Recognition will describe some ways of recognizing icy road conditions.
- When driving in rain at near freezing temperatures:
  - Feel for ice along front of mirror
  - If ice is present, it is usually followed by ice on roadway.
- When in doubt, test surface traction
  - Make sure no one is following tractor-trailer
  - Apply brake gently to see if vehicle skids

Visual 5 Skidding and Jackknifing

Skidding and Jackknifing

NOTE: Skidding and jackknifing will be discussed further in Unit 3.3 Skid Control and Recovery. This preview is intended just to show hazards of foul weather operation.

Three Basic Causes

- Over acceleration
- Overbraking
- Oversteering

Over Acceleration

- Causes drive wheel tires to spin (too much power)
- Results in tractor skidding

Overbraking

- Braking too hard for surface conditions
  - Excessive application of service brakes
  - Sudden release of accelerator
  - Untimely use of engine brake
- Can result from
  - Driving too fast
  - Not looking far enough ahead
  - Insufficient following distance
- Result
  - Wheels lock up
  - Tractor and or trailer skids
  - Produces jackknife

- Often occurs when driver feels tractor skidding
  - Instinctive reaction
  - Aggravates skid

Over Steering

- Driver negotiates a turn too fast or turns steering wheel too abruptly
- Drive wheel tires still want to go straight
- Not enough friction between tire and road to hold
- Results
  - Causes trailer to skid or swing out (braking will magnify skid)
  - Tractor-trailer jackknifes

Adverse Weather Operation

Proper Operation on Slippery Surfaces

Visual 6 Checklist for Operation on Slippery Surfaces

Drivers need to realize that trips on icy roads are going to take longer

Start Gently

- When first starting, get the feel of the road
- Don't hurry

Adjust Turning and Braking to Conditions

- Make turns as gradually as possible
- Don't brake any harder than necessary
- Avoid use of engine brake if possible

Check Mirrors

- Check trailer when braking to detect possible jackknife while there is time to recover
- At night, sudden appearance of trailer lights in mirror indicates jackknifing trailer

Adjust Speed to Conditions

- Don't pass slower vehicles unless necessary
- Operate at reduced speeds
  - Select an appropriate speed and watch far enough ahead to maintain a steady speed in order to avoid having to slow or speed up
  - Negotiate curves and turns at slower speeds
    - Don't brake while in curve
    - Achieve proper speed gear range before curve
    - Maintain power through curve
- As temperature rises
  - Ice melts
  - Becomes more slippery
  - Speed must be reduced even further

Adjust Space to Conditions

- Avoid driving along side other vehicles
  - Keep out of the pack
  - Leave yourself room for emergencies
- Maintain a larger following distance
- When traffic looks congested up ahead
  - Hang back
    - Stop if necessary
  - Wait for it to clear
- Anticipate stops (prevents panic stopping)
- Apply brakes with pumping motion
    - Will discuss in Unit 3.3 Skid Control

Wet Brakes

- When driving in heavy rain or deep standing water, brakes will get wet
  - Brake linings will slip on drum or disc
  - Causes brakes to apply unevenly or to grab
  - Can cause
    - Lack of braking power
    - Wheel lockup
    - Veering to one side of the lane or the other
    - Tractor or trailer jackknife

- Standing water
  - Avoid if possible
- If not, driver should
  - Slow down
  - Place transmission in appropriate low gear
  - Place foot lightly on brake
    - Keeps mud, rocks, and water from getting in-between linings and drum or disk
  - Increase engine speed (rpm)
  - Accelerate through water
- When out of water
  - Keep in low gear
  - Keep foot on brake
  - Increase rpm to keep from stalling
  - Maintain light pressure on brakes for a short distance to dry them out
  - Release brakes
  - Make test stop
    - Check behind to make sure no one is following
    - Apply brakes to be sure they are working properly
    - Make sure they apply evenly
  - Continue trip

Caution: Perform above process carefully so as not to damage vehicle components

Summary of Adverse Weather Operation

- A driver should be aware of his vehicle's and his own limitations
- By doing this, he can recognize when conditions are too hazardous to drive
- The best way to prevent accidents in adverse weather conditions:
  - Adjust speed, braking, steering, and space cushion to weather conditions
  - Suspend driving when conditions get very bad

Visual 7 Freeing Stuck Vehicle

Freeing a Stuck Vehicle

- Avoid conditions that cause vehicle to get stuck
- Recognize hazardous conditions such as
  - Soft berm (soft dirt on roadside)
  - Deep snow
  - Muddy roads
  - Icy, slippery driving surface

- When in doubt, avoid driving on suspicious surfaces
  - When making deliveries in construction areas
  - When pulling off the road for repairs

- When vehicle is stuck
  - Avoid spinning drive wheels or rocking
    - It will only dig vehicle in further
    - On ice, spinning wheels
      - Generate heat
      - Warms ice under tires
      - Reduces traction by one-half
  - Use traction aids
    - Dig out from front of wheels
    - Scatter sand or gravel in wheel path
    - Lay loose chains in front of wheels
    - Use spray on traction enhancers

  - Lock interaxle differential (if applicable)
  - Use higher gear, e.g., second or third
    - Reduces force applied to wheels
    - Gives smoother application of force
    - Helps keeps wheels from spinning
  - Start with steering wheels straight ahead
    - Reduces resistance from front wheels
    - Turn wheels after the vehicle is moving
  - If you have to start with wheels cramped
    - Gently accelerate
    - Turn steering wheel back and forth (3/8 to 1 inch)
    - Irons out path for front wheels
  - Smoothly and gently accelerate vehicle
    - Ease off accelerator at first sign of wheels slipping
    - Allowing wheels to spin can cause
      - Spinout
      - Wear on differential

NOTE: All procedures listed (e.g., traction aids) might not be needed; however, all should be tried before calling a tow truck (if possible).

Towing

- When a tow truck is necessary, driver should
  - Remember he is still responsible for equipment and cargo
  - Maintain control--driver in charge, not tow truck operator
  - Supervise the operation
  - If operator does something wrong and unsafe
    - Stop operation
    - Correct problem
  - Play out enough cable or chain
    - Should be long enough to keep rig, once freed, from lurching into tow vehicle
  - Hook cable or chain to rig yourself
    - Front--pass through hole in bumper
      - Do not hook to bumper
      - Attach to tow hooks protruding from frame (if available)
      - If not, hook to solid portion of frame or frame cross member
      - Be careful not to get the chain around the steering tierod or spring shackles along with the axle
    - Rear--tow hooks or frame
  - Tractor should accelerate gently
    - Just enough to turn wheel slowly
    - Helps tractor-trailer climb over dirt, debris, small bumps
  - Before vehicle is towed, agree on towing procedure
    - Direction
      - The direction the towing vehicle is to pull
      - The direction the tractor-trailer is to be steered
    - When to stop
      - Tractor-trailer should signal telling vehicle when to stop (because rig is clear or to prevent further difficulty)
      - Driver of towing vehicle and tractor-trailer should agree on appropriate signal
      - Horn signal is commonly used
- When truck has been pulled clear
  - Signal tow truck driver to stop accelerating
  - Apply tractor-trailer brakes
  - Allow tractor-trailer to bring the tow truck to a stop
  - Prevents tractor-trailer from rearending the tow truck

Caution: Keep all bystanders well out of the way to prevent injuries should the tow cable snap

If Vehicle Breaks Down (Remote Areas)

- Exposure to wind and cold dangerous
  - Can result in frostbite
  - Stay in cab -- put on extra clothing to conserve body heat
  - Use your food/beverage supply carefully in case help is slow to arrive
  - Don't try to walk for help--you may not make it

- Stay with rig so snow plow crews can have you move it once they plow you out
- If you must leave your vehicle, leave a note on steering wheel as to where you are
- If your engine will run watchout for exhaust fumes in cab -- keep window slightly open

Smart drivers always carry a supply of drinking water, candy bars, fruit and extra clothing with them during periods of adverse weather in case they do get marooned in some remote area -- remember it could be 2 or 3 days before highway crews can reach you

2. HOT WEATHER (20 minutes)

Visual 8 Checklist for Hot Weather Operation

Vehicle Inspection

Tires

Check mounting and inflation pressure (see manufacturer's specifications)

- Inspect frequently enroute
  - Every 2 hours or 100 miles
    - Proper pressure and temperature
  - Increases of 10-15 psi are common
  - Any increase over 15 psi or if tire too hot to touch (check with the back of your hand, not your palm)
    - Don't drive any further
      - Will blow out
      - Catch fire
    - Let tire cool off
    - Correct problem, e.g., improper load distribution, cold, inflation pressure too high
    - Never bleed tires when hot
      - Let cool off then check pressure

- When running on recapped or retreaded tires
  - Increased pressure, hot temperature can cause bonding to come loose
  - Tread will separate from the body of the tire
- Results
  - As tread separates, the tire will blow
  - Flying tread could tear air line or electric cable

Engine Lubrication

- Oil helps keep engine cool
- Frequency check on oil temperature gauge (see manufacturer's specifications for proper operating temperatures)
- Oil should be kept at proper level (do not underfill or overfill)

Engine Cooling System

- Vital for proper engine operation
- Carry extra coolant
- Cooling system should be kept at full and clean
- Keep eye on water temperature gauge
- If coolant has to be added
    - Idle engine
    - Let engine cool
    - Run at sufficient rpm to circulate fluid
    - Remove radiator cap -- very carefully
        - Use rag
        - Remove cap slowly
        - Keep face and body clear
            - Add coolant slowly

Engine Belts

- Check for cracking, fraying, or other signs of wear
- Check belt tension
- Broken where it's slipping belts will cause fan and/or water pump to stop operating
- Result will be overheating

Hoses

- Check for cracks, cracking, fraying, kinks, or collapsing when engine is accelerated
- Coolant must circulate freely to keep engine operating at proper temperature
- Must be in top shape for engine to run cool

Driving in Desert Conditions

Watch for Washes (Flash Floods) in Desert

- Secondary roads are frequently constructed through dry riverbeds
- In heavy rain the road can become quickly flooded
- Leave such areas if rain is imminent

Watch for Bleeding Tar

- Tar on roads frequently rises to the surface in very hot weather
    - Spots where tar is "bleeding" are very slippery

Avoid Continuous High Speeds

- Creates more heat for tires and engine
- Heat cannot be dissipated in continuous high speed driving
- Increases chances of tire failure and engine overheating

If Vehicle Breaks Down (Remote Areas)

- Exposure to heat and sunlight dangerous
  - Body fluids are used up rapidly in the desert, resulting in dehydration
  - Prolonged exposure to sun can cause sunstroke
  - Stay out of sun
  - Do not stray away from vehicle
  - Sit in cab or under trailer
  - Wait for help to come

3. MOUNTAIN DRIVING (1 hour)

Visual 9 Checklist For Mountain Driving

Gravity or Weight--Force Which Pulls an Object to Earth

Climbing

- Gravity adds to load weight
- Pulls vehicle down
- Increases horsepower required to move vehicle
- Affects passing ability

Descending

- Gravity pulls vehicle to earth, increases momentum
- On steep grades, can pull vehicle offroad, e.g., curves, bumps, loose gravel
- Brakes should always be checked prior to mountain driving

Mountain Pre-inspection

Prior to starting mountain driving, drivers of vehicles equipped with air brake systems should check

- Compressor maintaining full reservoir pressure
- Pressure drop on full application is within limitations
- Slack adjusters for push rod travel and take up slack
  - (Procedures for adjusting brakes to be covered in Unit 4.2)
- Audible air leaks, applied and released
- Security of glad hands and air lines
- Drums for overheating
  - Don't touch drums (could burn hands)
  - Hold back of hand close to drum
  - Some heat is normal; check for unusually high temperature
  - Trailer protection valve operation

Operating on Upgrades

Shifting

- If rpm fall, downshift into next lower gear
    - Gravity will cause the vehicle to slow during down shift
    - Must adjust by:
        - Shifting before rpm reach the bottom of the range
        - Completing shift quickly
    - Downshift until you find a gear that will allow rpm to be maintained

Position

- Position vehicle in far right hand lane or in truck lane
- Be patient
- Stay in lane
- Don't pass if it can't be done quickly
    - An uphill truck race blocks traffic
    - Antagonizes public makes worst possible public relations
    - Can cause other drivers to become so impatient they attempt to make a dangerous pass

Watch Gauges

- Check coolant and oil temperature gauges
    - Pulling a load up a long grade can cause overheating

Operating on Downgrades

Use of Gears

- Avoid any attempt to downshift while descending
    - Place in low gear at top of downgrade
    - Use same gear that is required to ascend the same grade or better yet, one gear lower
- Attempt to shift might result in getting hung up between gears
    - Would lose the benefit of engine braking
    - Service brakes insufficient to restrain a tractor-trailer
    - Will be unable to control speed of vehicle
- Pay attention to signs indicating angle and length of grade
- Place vehicle in same gear used to ascend grade or better yet, one gear lower (essential on steep winding downgrades)
- Let drive train assist in controlling downhill speed
    - This causes the drive shaft to resist turning
    - This in turn causes tractor drive wheels to resist turning
    - This form of braking assists service brakes
- Never shift into neutral and coast
    - Extremely unsafe
    - Illegal

Proper Braking Technique

Maintain enough pressure to keep engine speed in normal rpm range
  Light pressure adequate if transmission in proper gear
  Use steady pressure

MYTH: Applying brakes intermittently (fanning) allows air to circulate round the brakes and keep them cool

Intermittent braking requires heavier pressure than steady application
Heavier pressure builds up more heat
Eventually, the heat will cause the brakes to fade
  Brake drums become extremely hot and elongated or egg shaped
  Shoes and drums no longer contact each other fully
  Brakes eventually become useless, may even catch fire
  All of this can occur within matter of minutes (depending on load and downdrade) so watch it!
  Tractor-trailer runs out of control
  Can result in a very serious, possibly fatal accident
Amount of cooling between applications is negligible
Intermittent braking builds up far more heat than steady braking
Proper braking procedure requires
  Prior selection of appropriate gear
  Steady application of foot brake

Visual 10 Auxiliary Brake or Speed Retarders

Auxiliary Brakes or Speed Retarders

Function

Auxiliary brakes or speed retarders
  Reduce the vehicle's forward motion without using service brakes
  Reduce the burden upon primary service brakes, allowing them to remain cool when they are needed
  Work in conjunction with the service brakes to allow control to be maintained on long down grades
    They may be efficient to keep rpm's in the safe operating range and also
    If rpm's reached the upper limit, it will be necessary to apply service brakes, as described earlier, to keep the vehicle under control

Types

Engine brakes
Jacobs Manufacturing Company - "Jake Brake"
  Mack Truck - "DYNATARD:
    Eliminates power stroke
    Converts engine to air compressor (for braking purposes)
    Fuel injection stopped
    Exhaust valves open
  Expels compressed air
    Retards piston movement

- Exhaust brakes
  - Williams Air Controls - "Blue Ox"
  - Mercedes Trucks - "Exhaust Brake"
  - Backs exhaust gases up into engine
  - Creates pressure (40 to 50 psi)
  - Retards piston movement
- Hydraulic retarders
  - Caterpillar Tractor Company - "Cat Brakesaver"
    - Located between engine and transmission
    - Uses engine oil pumped against stator (fan like device) to retard drive shaft movement, slowing vehicle
    - Creates great deal of heat, which is carried away by engine oil.
  - Detroit Diesel Allison - "Allison's Brake Preserver"
    - Integral part of transmission
    - Uses transmission oil, forcing it under pressure into a cavity formed by the rotor and stator
    - Oil slows rotation of rotor, thus retarding vehicle movement
- Electric retarder
  - Jacobs Manufacturng Company - "Jake ER Brake"
  - Francoise Telma - "Telma Retarder"
    - Mounted in drive line
    - Electric current retards drive shaft rotation

Operation and Controls

- Engine and exhaust brakes
  - On/off manual control switch in cab
  - Some may have different positions for amount of retardation
  - Automatic switch
    - Foot taken off accelerator pedal
    - Clutch pedal depressed (Jake)
    - Brake automatically goes on
- Hydraulic retarders
  - Brake can be adjusted manually in cab
  - Has different levels of operation
  - The higher it's turned up, more effective it becomes
    - Also has treadle valve and may have clutch switch
- Electric retarders
  - Switch on - Electromagnet on
  - Switch off - Electromagnet off
  - Brake is either on or off (no in between)
  - The Jacobs electric retarder has a 4-position steering column switch--no throttle or clutch switch

Auxiliary brakes or speed retarders are desirable in any operation where service brakes are continually used (e.g., mountainous terrain, long descending grades)

Must know when--locations where permitted (noise ordinances), proper gears and rpm, weather conditions--to use retarders

Visual 11 Escape Ramps

Truck Escape Ramps

Function

To stop runaway vehicles on steep mountain grades

Location

Ramps placed in strategic locations (where vehicles often have trouble
Usually a few miles on either side of summit

Benefits

Escape ramps are designed to stop runaway vehicles safely without
- Injuring driver or passenger
- Damaging vehicle or cargo

Safety of Driver

- Ramps capable of stopping tractor-trailer (50,000 lbs GVW) traveling
  - 55mph within 450 feet after entering ramp
- Stopping sensation--same as hard lock wheel stop, dry pavement
- Driver, vehicle, and cargo still intact
- Escape ramps offer drivers an alternative to a runaway vehicle and a serious accident

Vehicle and Cargo Damage

- Ramps designed to sink vehicle (loose gravel, sand) or send it up an incline (grades up to 43 percent) not damage it
- Damage to vehicle and/or cargo generally limited to minor scratches, nicks, lost battery cover, etc.

Real life example

- Place
  - Highway U.S. 40 (Colorado)
  - Rabbit Ear Pass (9,650 foot summit)

- Vehicle and Cargo
  - Tractor-trailer (40,000 GVW)
  - Carrying steel beams
- Downgrade--7 percent
- Problem
  - Drivetrain failure
  - Brakes fail to respond
  - Runaway vehicle
- Escape ramp
  - Vehicle enters ramp traveling between 100-110 mph
  - Is stopped within 1,300 feet after entering ramp
  - Driver and passenger walk away unhurt
- Vehicle damage
  - Dent in cab
  - Battery cover missing

Total cost
$10 for two ramp markers
Cost of tow truck to free vehicle

Use

Be aware of escape ramp locations
When in doubt, use ramp
Things won't get better
May not have another chance
Try to enter the ramp squarely, not at an angle

Types (Four basic)

Gravity

Steep ascending grades
Loose material surface (pea gravel)
Length--300-2,000 feet
Width--12-45 feet
Grade--Plus 5 percent to plus 43 percent
Surfacing depth--6 to 36 inches
Mounds of gravel or sand at end of ramp

Sand Piles

Mounds or ridges are built on top of pile
High enough to drag undercarriage of vehicle
Length--85 feet - 200 feet
Height--10 feet
Top width--20 feet

Arrester Beds

Masses of loose material
Use friction
Flat grade
Length--300-700 feet
Surface depth--18 inches of pea gravel

Combination Ramp and Arrester Bed

Relies on loose surface material
Length--500 - 2,200 feet
Width--18 - 50 feet
Grade--Plus 1.5 percent to minus 6.7 percent
Surface depth--12 inches of pea gravel

Summary

Recognizing safety role of escape ramps is vital
Drivers are confronted with two choices:
Use escape ramps
Save own life and possibly others
Save their vehicle and its cargo (possibly sustaining minor damage)
Probably pay for having vehicle winched back onto highway

Pay consequences for not using ramps
    - Possibly lose their life and that of their passenger (if any) or sustain serious injury
    - Endanger other people and vehicles
    - Wreck their vehicle
    - Lose their cargo

Escape ramps will save lives, equipment and cargo

4. SUMMARY (15 minutes)

Students Should Keep in Mind Five Basic Points

1. Know your vehicle
    - Its systems and their limitations

2. Reduce speed
    - Magnifies mistakes

3. Prepare for the worst

4. Make smooth gradual changes
    - Turning
    - Changing lanes
    - Accelerating
    - Decelerating
    - Stopping

5. Think ahead - ANTICIPATE

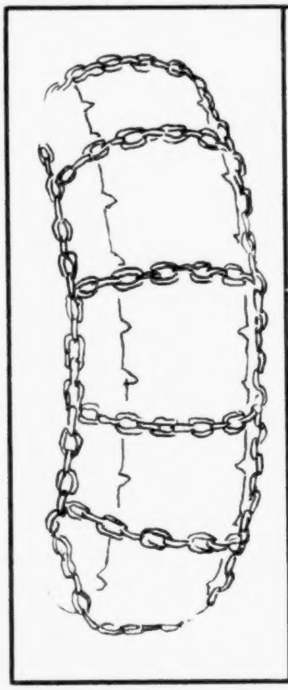
NOTE: Instructor should allow time for question and answer period, if necessary. Ask students how they would handle various situations and what preparations they would make for adverse weather trips, or other such situations.

Special Adverse Weather Checklist For Pretrip Inspection

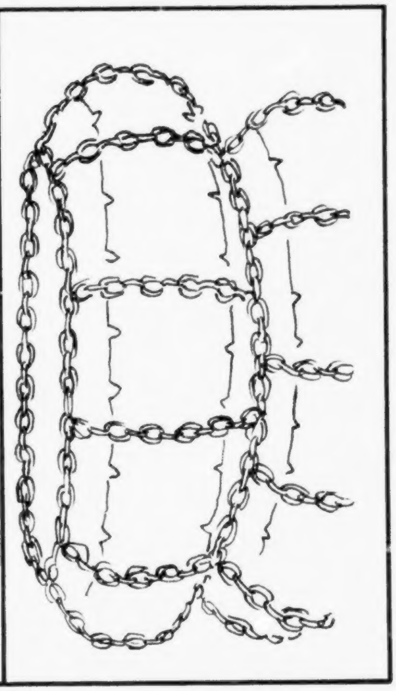
- Antifreeze
- Heater/Defroster
- Wipers/Washers
- Tires
- Chains
- Brakes
- Lights
- Windows, Mirrors, and Reflectors
- Hand and Toe Holds
- Radiator Shutters
- Exposed Wiring and Hoses
- Fuel Tank
- Muffler and Exhaust System
- Fifth Wheel
- Personal Gear and Supplies
- Weather Reports–Road Conditions

Visual 2

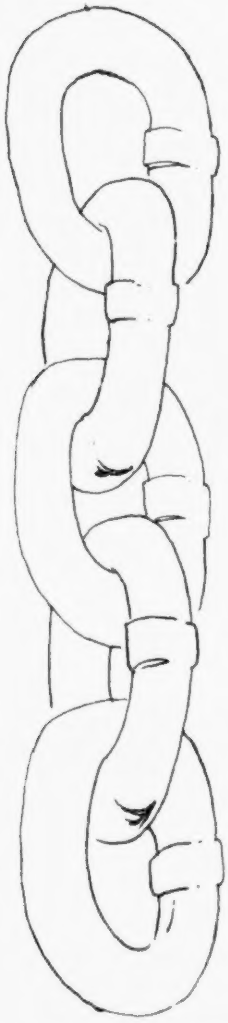
Tire Chains



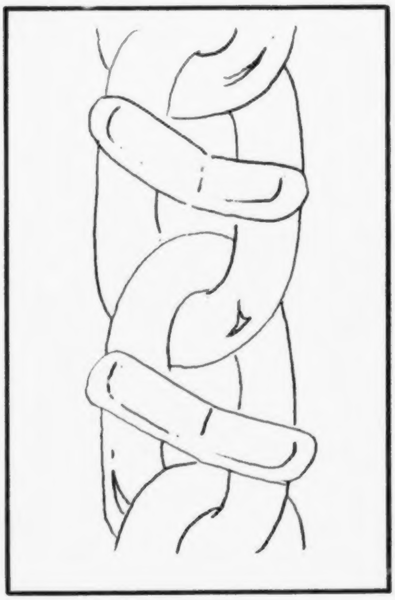
Single Wheel Type



Dual Wheel Type



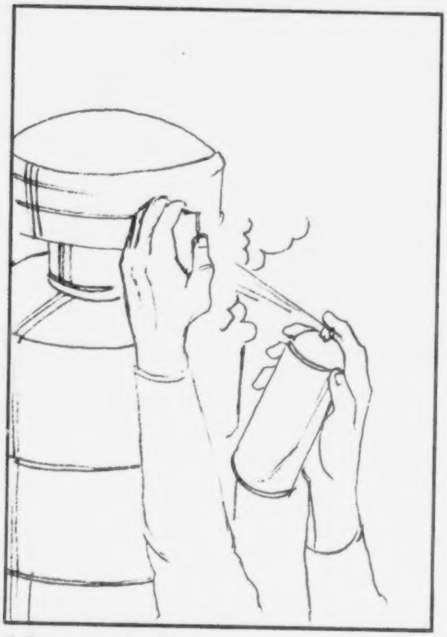
Conventional Chain Links



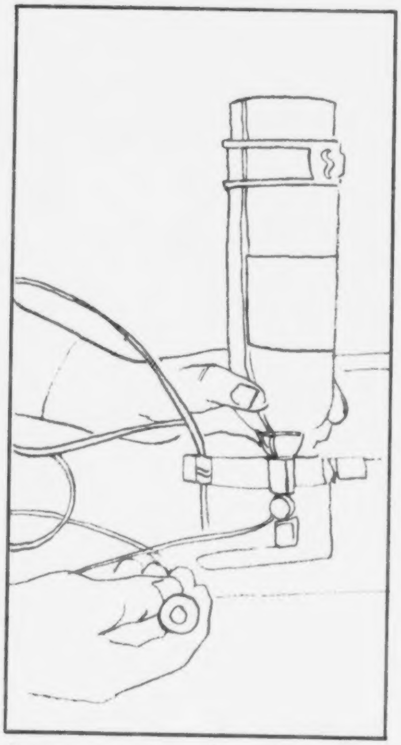
V-Lug Reinforced Chain (Only on Cross Chains)

Visual 3

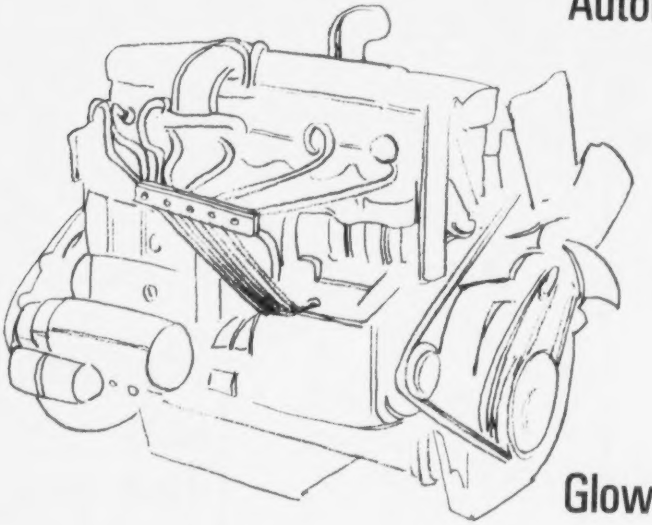
Cold Weather Starting Aids



Manual Ether Application



Automatic Application



Glow Plugs

Visual 4

Primary Hazards

Reduced Visibility

Reduced Traction

- Road Surface
  - Different Surfaces–Different Degrees of Traction
  - Be Aware of Changing Conditions
- Speed
  - Speed Magnifies Mistakes
  - Determine Speed Wheels Roll Without Spinning
  - Adjust Speed to Changing Road Surfaces and Conditions

Visual 5

Skidding and Jackknifing

Causes:

Overacceleration

Overbraking

Oversteering

Checklist for Operating on Slippery Surfaces

Trip Time on Icy Road Will Take Longer

- Start Gently
- Adjust Turning and Braking to Conditions
- Check Mirrors
- Adjust Speed to Conditions
- Adjust Space to Conditions
- Avoid Wet Brakes

Freeing Stuck Vehicle

Avoid if Possible

- Soft Berm
- Deep Snow
- Muddy Road
- Slippery Driving Surface

When Stuck

- Don't Spin Wheels
- Use Traction Aids
- Lock Interaxle Differential
- Place in Higher Gear
- Accelerate Gradually

When Using Tow Truck

Remember: You Are Responsible for Your Vehicle and Cargo

You Should Maintain Control

You Should Hook Cable to Chain to Vehicle

Checklist for Hot Weather Operation

Check

- Tires
- Lubrication
- Cooling System
- Belts
- Hoses

Adjust

- Watch for Flash Flood Conditions in Desert
- Watch for Bleeding Tar
- Avoid High Speed Conditions
- Stay With Vehicle

Checklist for Mountain Driving

Upgrades

- Downshift Until You Find Gear That Will Maintain RPM's
- Position Vehicle in Right Lane
- Don't Pass

Downgrades

- Never Downshift While Descending
- Place Vehicle in Same Gear Used to Ascend Grade or Better Yet a Lower One
- Let Drive Train Assist in Controlling Downhill Speed
- Maintain Steady Brake Pressure—Don't "Fan" Brakes
- Watch Air Brake Pressure

Auxiliary Brakes or Speed Retarders

Four Basic Types (and Examples)

- Engine Brakes

  Jacobs Manufacturing Company's–"Jake Brake"

  Mack Truck's–"Dynatard"

- Exhaust Brakes

  Williams Air Controls–"Blue Ox"

  Mercedes Trucks–"Exhaust Brake"

- Hydraulic Retarders

  Caterpillar Tractor Company's–"Cat Brake Saver"

  Detroit Diesel Allison's–"Allison Brake Preserver"

- Electric Retarders

  Jacobs Manufacturing Company's–"Jaker"

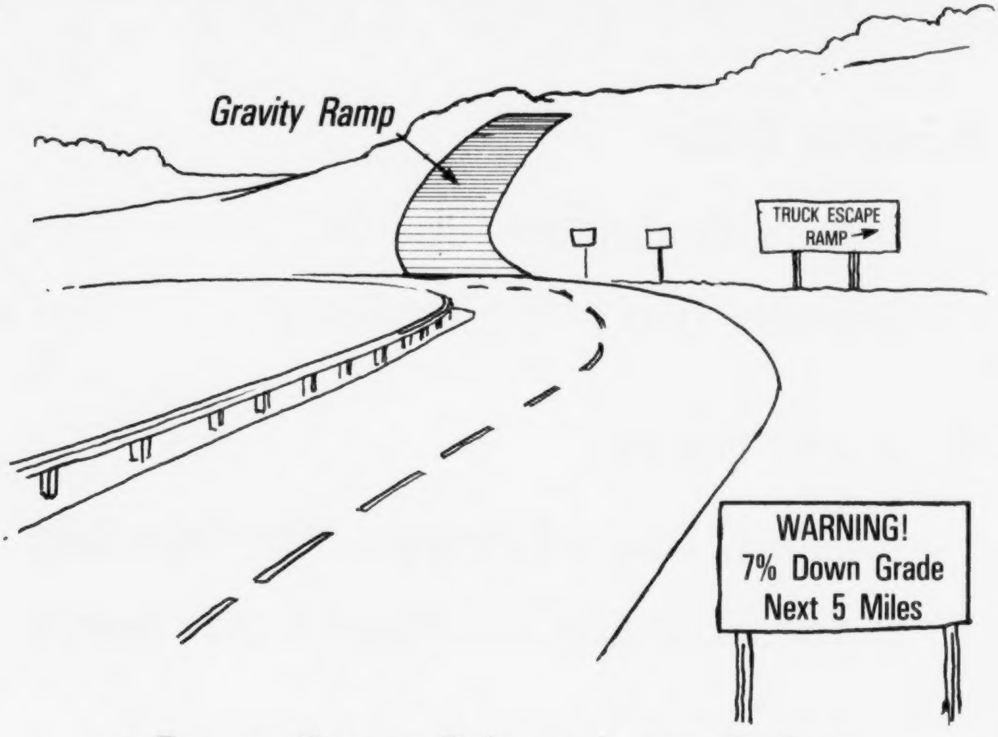
  Francoise Telma–"Telma Retarder"

Visual 11

Escape Ramps

Types

- Gravity
- Arrester Beds
- Combination Ramp and Arrester Bed
- Sandpiles


Gravity Ramp
TRUCK ESCAPE RAMP →
WARNING!
7% Down Grade
Next 5 Miles

- Escape Ramps Rely on Loose Surface Material (e.g., Pea Gravel, Sand) to Stop Vehicle
- Some Also Use Steep Positive Grades (e.g., Gravity Type Ramp)

LESSON 2 TECHNIQUES USED DURING EXTREME CONDITIONS (RANGE)

Overview

Time Alloted: 4 hours

Prerequisites: Unit 2.6, Lesson 1

Purpose:

The purpose of this lesson is to provide practice in use of tire snow chains and towing chains. The instructor will demonstrate the proper procedures for mounting snow chains as well as the proceudres for using tow chains and cables to free stuck vehicles. Students will be required to mount and remove snow chains and participate in the towing exercise. Time will be allowed for questions and answers after each demonstration.

Materials

Instructional Aids

None

Student Material

Mounting and Removing Snow Chains and Freeing Stuck Vehicles Checklist, in Unit 2.6 of Student Manual

Instructor Material

Mounting and Removing Snow Chains and Freeing Stuck Vehicles Checklist, in Unit 2.6 of Student Manual

Snow chain manufacturers instructional material (contact your local supplier)

Equipment

Snow chains, several sets of both the single and dual wheel types

Wheel chocks and run-up blocks

Two tractor-trailers - one used to tow and one to be "pulled out"

Tow chains and cables of various types

Facilities

This lesson should take place on the driving range, in case of foul weather snow chain exercise can take place in shop or other building if available

Content

Activity or Topic	Approximate Time
1. MOUNTING AND REMOVING SNOW CHAINS	2 hours 30 minutes
2. FREEING STUCK VEHICLES	90 minutes
	4 hours

1. MOUNTING AND REMOVING SNOW CHAINS (2 hours 30 minutes)

Purpose

The purpose of this exercise is to develop student skill in mounting and removing snow chains.

Range Layout

No specific range layout required.

Directions

1. Instructor will demonstrate to each group the proper procedure for mounting and removing snow chains.

2. Groups should be small enough for students to easily observe demonstration.

3. Thereafter, groups break up into usual 3 person teams.

4. Student instructor ratio should be such that each student will be able to have individual attention if needed.

5. Several tractor-trailer combinations should be utilized. This will allow more than one team to participate at the same time.

6. Each student will then be required to safely and properly mount and remove a set of snow chains.

7. Students will rotate from actual participation to observing other students as they mount and dismount the chains.

8. One team of students will mount single tire chains while the other mounts dual type chains. After snow chains have been mounted, and removed, the two teams will switch vehicles so that each team gains experience with both types of snow chains.

Observation

The instructor will observe for failure to perform the following procedures properly.

Mounting

Check chain condition
Eliminate twists
Drape chains over tire
Open ends of cross-chain hooks away from tire
See that fasteners are on the trailing ends of side chains
Tuck first cross-chain under front of tire
Move vehicle until fasteners are hub-high
Avoid driving over fasteners
Straighten and center

Lift ends of side chains to determine which links will be hooked into fastners

If installing on duals, fasten

1. Center chain
2. Inner chain
3. Outer chain

If installing on singles, fasten

1. Inner chain
2. Outer chain

Be sure chains are snug

  Slack adjusters should be used
  Vehicle should be driven forward a few feet and checked to make sure they are snug
  After driving about 5 miles, stop and tighten chains again
  Loose chains wear faster and cause damage

Removing

Unhook cross chains from side chain fasteners on the outside (whether on duals or singles)
Unhook inside cross chains (duals)
Spread chains on ground
Drive vehicle off chains
Do not run over fasteners
Remove chains

Instructor should watch for the following common problems:

Chains Too Tight

Will result in gouged or worn tires.

Chains Too Slack

Will result in premature chain failure.

2. FREEING STUCK VEHICLES (1 hour 30 minutes)

Purpose

The purpose of this exercise is to develop the student's ability to understand correct procedures in use of tow chains and/or cables to free stuck vehicles safely.

Range Layout

No specific range layout required.

Directions

1. The exercise will last a total of 90 minutes.

2. Before the student practice session, the instructors will demonstrate to the class the proper procedure for extricating a stuck vehicle, using tow chains and/or cables. The instructor will operate the pulling vehicle and an assistant instructor the pulled vehicle, i.e., the vehicle that is being "pulled out."

3. The class will be divided into groups, containing three students each. One student from each group will make the chain connections. The other two will operate the towing and towed vehicles.

4. Students will rotate positions till each has performed at all three stations.

5. Two forms of towing should be illustrated:

   Front-to-front--Front of towing vehicle faces front of towed vehicle in order to allow eye-to-eye contact between drivers.

   Back-to-front--Rear towing tractor is backed up to front of towed tractor. Used when front-to-front connection is not possible.

   Tractor-trailers should be placed back-to-back and/or back-to-front on the range.

6. Observer students should stand well back from vehicles in order to avoid injury in case the cable should break.

Observation

The instructor will observe for failure to perform the following procedures properly

Play Out Enough Cable or Chain and Hook

- Front
    - Tow hooks (if available)
    - If not, hook to frame or frame cross member
- Rear
    - Tow hooks or frame

Tow Vehicle

- Place in low gear
- Creep forward till chain or cable is tight
- Do not spin wheels
- Gradually pull vehicle onto firm surface

Towed Vehicle

- Place transmission in low gear (or reverse)
- Release clutch
- Accelerate gradually (assisting tow vehicle)
- Do not spin wheels
- Straighten wheels
- When on firm surface
  - Honk horn signaling tow truck to stop
  - Move vehicle up slightly slacking cable or chain
- Disconnect cable or chain

Instructor should watch for the following common problems:

Excessive Acceleration

Chain or cable will jerk and wheels will spin. Slipping or side movement of vehicles will result.

Shortage of Slack

Chain or cable between vehicles is too short, resulting in reduced maneuverability and possibly a collision.

UNIT 2.7
PROFICIENCY DEVELOPMENT:
SAFE OPERATING PROCEDURES

UNIT 2.7 PROFICIENCY DEVELOPMENT: SAFE OPERATING PROCEDURES

PURPOSE

The purpose of this unit is to provide students an opportunity to refine and polish, within the highway traffic environment their vehicle handling skills learned in Units 1.4, 1.8, and the safe and fuel efficient operating practices learned in Units 2.1 through 2.6. Student performance will be closely monitored by instructors to see that students progress toward the level of proficiency required for graduation and to identify students who are not progressing satisfactorily in order that they may be provided counseling and/or remedial instruction as may be required.

It is important for instructors to go back and review the general instructions entitled Street Lessons in the introduction of this manual to refresh themselves on items covered in this unit such as:

- overnight and/or lengthy student trips
- legal requirements for such trips
- student solo type trips
- 1,000 miles actual and 38.5 hours of behind the wheel time for each student prior to graduation
- permissable use of the last few hours of this unit to conduct the road test portion of the Final Examination Test Battery

OBJECTIVES

This unit introduces no new performance, knowledge, skills, or attitude objectives. The 70.5 hours (required minimum time) of in- vehicle instruction provided in this unit are intended to allow students to develop their proficiency relative to all objectives to a level needed to pass the Road Test portion of the Final Examination Test Battery.

LESSONS

Lesson 1.	**Procedures for Safe Operation (Classroom)**	**1 hour**
Lesson 2.	**Practice in Safe Operation (Street)**	**70 hours 30 minutes**

LESSON 1 PROCEDURES FOR SAFE OPERATION (CLASSROOM)

Overview

Time Allotted: 1 hour

Prerequisites: Unit 2.5

Purpose:

The purpose of this lesson is to enable students to combine the practices of visual search, communication, speed management, and space management in carrying out the basic highway traffic maneuvers of lane changing, passing, merging, exiting, turning and parking. The instructor will guide students in developing a specific set of procedures for carrying out each of the maneuvers.

Materials

Instructional Aids

Visuals 1-7

Student Material

Safe Operating Procedures Checklist, in Unit 2.7 of Student Manual

Instructor Material

Safe Operating Procedures Checklist (at end of Lesson 2 in this unit)

Grease pencils for marking visuals

Content

Activity or Topic	Approximate Time
1. LANE CHANGING	10 minutes
2. PASSING	10 minutes
3. MERGING	10 minutes
4. EXITING	5 minutes
5. TURNING	10 minutes
6. PARKING	10 minutes
7. PREPARATION FOR STREET LESSONS	5 minutes
	1 hour

1. LANE CHANGING (10 minutes)

Throughout this and the following exercises, the instructor should assist the students in arriving at the appropriate procedures for carrying out maneuvers by coaching them in piecing together the practices learned in the previous units. The following method is suggested:

1. Place the visual called for upon the overhead projector.
2. Using a grease pencil, and proceeding one step at a time, draw upon the visual the path taken by the tractor-trailer in completing the maneuver.
3. At each step in the maneuver, call upon the student to identify the safe operating practice that should be employed. These practices are given step-by-step, under each of the maneuvers described below.
4. As the students identify appropriate safe operating practice, have them review the reasons why the practice is necessary.

The specific practices listed for each maneuver are sufficient for its safe execution. However, should the school employ a somewhat different procedure, it may be used so long as it includes all other individual practices that are listed under the maneuver.

Visual 1 Lane Change

Lane Changing

Coach students in arriving at the following procedure for carrying out a lane change.

Check Mirror

Check the side mirror in the direction of the intended lane change
This preliminary check is needed to see if the lane to be entered is clear of adjacent or overtaking traffic

Assess Gap

Look to see that there is a large enough gap to allow the tractor-trailer to make a lane change and still leave a 2-second gap behind the trailer
Delay any decision to change lanes until an adequate gap appears

Activate Signal

Signal the lane change even if there is not a sufficient gap
Giving a signal may encourage other drivers to yield and create a gap
Signals should be made well enough in advance to allow vehicle hiding in any blind spot to see signal and make adjustment

Recheck Mirror

If there was an adequate gap available, make sure it is still available
If there was not a gap available before, there may be now

Initiate Partial Lane Change

Wait a few moments after signaling has been given to allow hidden vehicles to adjust
Gradually change position until the tractor-trailer straddles the lane divider and encroaches upon the adjacent lane

Pause

Maintain the partial lane change position for a few moments
This allows time for any driver who failed to notice the lane change signal to respond to the movement of the tractor-trailer

Recheck Mirror

Look for any vehicle that may have been "flushed out" by the partial lane change

Complete Lane Change

If the adjacent lane is clear, complete the lane change
Move steadily and quickly into the center of the adjacent lane

Cancel Signal

2. PASSING (10 minutes)

With the aid of the transparency and using the approach described in the previous exercise, coach students in arriving at a procedure for a safe passing maneuver on multi-lane highways.

Visual 2 Passing

Pass on Left

Avoid passing on the right if at all possible
Other drivers don't expect to be passed on the right
The sound of the truck may "spook" another driver into a lane change to the right

Pull Out

Review the lanes change procedure in the previous exercise as the first step in a passing maneuver
The student should be able to describe all of the steps

Pass Vehicle

- Complete the pass as quickly as possible
- Do not linger in the other driver's blind spot
- Watch left front wheel of vehicle being passed

Check Mirror

- Check the mirror on the side of the vehicle in which the next lane change is to be made (to pull back into lane)
- Don't assume a gap between the tractor-trailer and the vehicle just passed
- The driver who was overtaken may have speeded up in order to keep from being passed

Assess Gap

- Allow 2 seconds between the end of the trailer and the vehicle that has been passed
  - On a sunny day, the shadow of the truck and the vehicle that was passed may have helped in judging the gap between the two vehicles
  - Allow an ample margin for error when using only the mirror to judge distance from the vehicle that was passed
- There is nothing to be gained by being over anxious in returning to the lane
- Don't accept another driver's signal that it is safe to pull back

Signal

- Activate turn signal well before pulling back into lane
- Use of the signal allows the driver who was passed to adjust if the truck driver has misjudged distance
  - Can drop back to leave a larger gap
  - Can sound horn to warn the driver of the truck
- Discourages overtaking driver from trying to squeeze between the truck and the vehicle that was just passed

Return to Lane

- Wait until the next lane is clear
- Return steadily but quickly to the original lane

Cancel Signal

- Cancel turn signal as soon as you are back in the lane

3. MERGING (10 minutes)

Coach students on safe merging procedures.

Visual 3 Merging

Steps in Merging Safely

Check Main Road

- Start looking for a gap as soon as there is a good view of the main road
- Try to judge the time and distance of the gap from the point at which the truck will merge onto the highway
- Finding a gap early allows use of the entire onramp and acceleration lane to adjust speed

Activate Signals

- Putting on the signal indicates to motorists on the main road of the driver's intent to merge
- Signaling also encourages motorists on the main road to give way to the truck
  - May change lanes
  - May slow down

Align the Rig

- Upon the acceleration lane, turn the truck so that it is driving parallel to the roadway
- Driving parallel to the roadway gives a better view of the main road in the mirror

Check Mirror

- Plane mirror
  - Use the plain mirror to observe the selected gap as it overtakes the truck
  - The convex mirror creates too much distortion for judging the gap accurately
- Convex mirror
  - Check for vehicles in far lanes trying to move into the gap
  - Check for vehicles on the ramp behind the trailer pulling out to merge into the same gap

Adjust Speed

- Adjust approach speed so that the tractor-trailer will arrive at the merge point at the same time the gap draws alongside
- Proper speed adjustment will help keep the driver from having to stop at the end of the ramp
- Having to stop at the end of the ramp requires a dangerous, low-speed merge

Enter Roadway

Enter the gap steadily and quickly
Avoid turning any more than is necessary (avoid an "S" maneuver)
Enter the first through lane
    Avoid cutting across lanes at the merge point
    If it is necessary to move to a far lane, make the necessary lane changes one at a time

Cancel Signal

Cancel signal promptly once maneuver is completed

4. EXITING (5 minutes)

Using the transparency, and the method described under Lane Change, help students to arrive at the following procedure for exiting from a highway or freeway.

Safe Procedure for Exiting

Visual 4 Exiting

Enter Correct Lane

Be in the lane closest to the exit well before hand
An early lane change lessons the chance of cutting off a hidden vehicle when approaching the exit

Signal

An early signal will prevent following drivers from attempting an unnecessary pass
A signal will alert the following drivers in case it becomes necessary to slow down before pulling into the exit lane

Maintain Speed

Avoid slowing down anymore than is necessary
A following driver will not generally expect a vehicle to slow down on the main road
Most exits are designed to permit a safe speed reduction after leaving the main road

Enter Exit Lane

Pull into the exit lane as early as possible
    Allows use of the full exit lane to reduce speed
    Prevents possible collision with another vehicle that has pulled off earlier and is overtaking the truck in the exit lane

Brake On Straightaway

Slow down as much as necessary before reaching the curved part of the exit ramp
Avoid braking in the curve
  Carrying too much speed into exit ramps can result in a jackknife or turnover
  One of the more frequent causes of tractor-trailer accidents

Merge

Use the merging procedure described earlier to enter the new highway or secondary road

5. TURNING (10 minutes)

Right Turns

Visual 5 Right Turns

Enter Right Lane

All right turns must be made from the right lane despite the large turning radius of the tractor-trailer
Enter lane as early as possible to avoid having to cut off another vehicle

Signal Turn

Signal well before reaching the intersection
To avoid confusion, don't signal until the previous intersection has been passed

Adjust Speed

Avoid having to brake in the turn
Entering turn slowly allows power to be applied during the turn for better control of the vehicle

Enter Appropriate Gear

Being in the appropriate gear before reaching the turn makes it unnecessary to shift gears during the turn
Not having to shift during the turn allows both hands to be kept on the wheel during the turn

Protect the Right Side

Prevent an overtaking vehicle from passing on the right while the rig is turning

Continuous turns

- Use when there is enough room on the cross street to make a wide turn, e.g., wide lanes, multi-lane street
- Keep the rig centered in the lane prior to turning

Buttonhook turns

- Review briefly the conditions that require of a button hook turn (turning into single lane street)
- Time the outward swing so that the trailer blocks off the right side of the road until tractor is part way through the turn

Check Right Side Mirror

- Use the appropriate mirror (westcoast, fender mirror) to watch the right side during the turns
- Check the clearance from the curb, parked vehicles, or roadside structures, (e.g., signs, light poles)

Yield to Opposing Traffic

- When intruding upon opposing lane, it is necessary to yield the right-of-way to vehicles in those lanes
  - Be prepared to stop when necessary
  - Stop before reaching opposing vehicles
- Allow enough room for the opposing vehicle to maneuver around the rig
- Not allowing enough room can create an impass since the tractor-trailer cannot safely back up

Adjust Position

- Stay in the lane entered
  - If it has been necessary to turn into a left lane, stay there
  - A through vehicle may be passing on the right
  - Exception: It is acceptable to return immediately to the right lane if the driver can be sure the trailer will block the right side until the turn is completed

NOTE: If a lane change is necessary, follow the procedure described under Lane Changing

Cancel Signal

- Wait until rig has completed turn and straightened out before canceling
- Canceling before shifting gears helps to form a "cancel-shift" habit

Left Turns

Visual 6 Left Turns

NOTE: Because of the similarity between left turn and right turn procedure, the students should be able to supply most of the steps in the procedure with minimum coaching.

Enter Correct Lane

Signal Turn

Adjust Speed

Enter Appropriate Gear

Protect Left Side

Avoid swinging to the right before starting left turn
A driver following the tractor-trailer may interpret it as a lane change and attempt to pass on the left

Yield to Other Vehicles

Oncoming vehicles proceeding straight through--the law requires yielding
Oncoming driver turning right (same direction as truck)--allow vehicle to proceed ahead of the truck
Vehicles from the left crowding intersections--letting them cross ahead of the truck leaves room for off-tracking of trailer

Check Left Mirror

Check rear of trailer for clearance for vehicles stopped at intersection

Enter Nearest Lane

Didn't cut across anymore lanes than necessary
Make any lane changes after turn has been completed
Exception: When turning left in two lanes, enter assigned lane as indicated by sign or pavement markings

Cancel Signal

6. PARKING PROCEDURES (10 minutes)

Coach students on safe parking procedures

Safe Parking Procedures

Visual 7 Parking Procedures

Approach Alley or Driveway from the "Sight" Side

Review with the students the danger of blindside backing
Illustrate the sight side approach on the transparency
- Activate flashers
- Activate before bringing the vehicle to a stop
- Help prevent drivers from pulling up behind truck preventing a backing maneuver

Check Path

Get out of the truck to check the path along which the vehicle will back
Check obstructions along the ground (curbs, small vehicles, etc.)
Check overhead clearances (e.g., signs, air conditioners, tree limbs)

Position Assistant

- Review the importance of having an assistant
  - Warn approaching drivers
  - Watch for hazards
- Review possible sources of assistances
  - Assistant driver
  - Local help

Position Correctly

To the rear of the trailer
Visible in the driver's mirror at all times

Back Slowly

Allow movement of the vehicle to serve as warning to drivers intending to pass behind it
Minimize the chance of collision with drivers who are attempting to squeeze by

Use Mirror

- Use plain mirror
  - Follow path
  - Observe assistant
- Use convex mirror to watch for vehicles or pedestrians converging on the tractor-trailer

Stop Before Reaching Dock

Get out and check clearances to the side, behind, and above
Open rear doors if clearance is restricted

Back Up to Dock

7. PREPARATION FOR STREET LESSONS (5 minutes)

Description of Onstreet Lessons

Duration

70 hours and 30 minutes of operation on streets of all types (laden and unladen)
Distributed throughout remainder of course

Routes

- Will drive through all possible environments
  - Urban
  - Suburban
  - Rural
- Routes will gradually increase in difficulty
  - More difficult road conditions (e.g., narrower lanes)
  - Increasing traffic density
- Overnight trip

Procedure

- Generally the same as previous Street Lessons
  - Alternate driving and observing
  - Use checklist to record driver errors
  - Pull over periodically to critiqe the driver

Use of Checklists

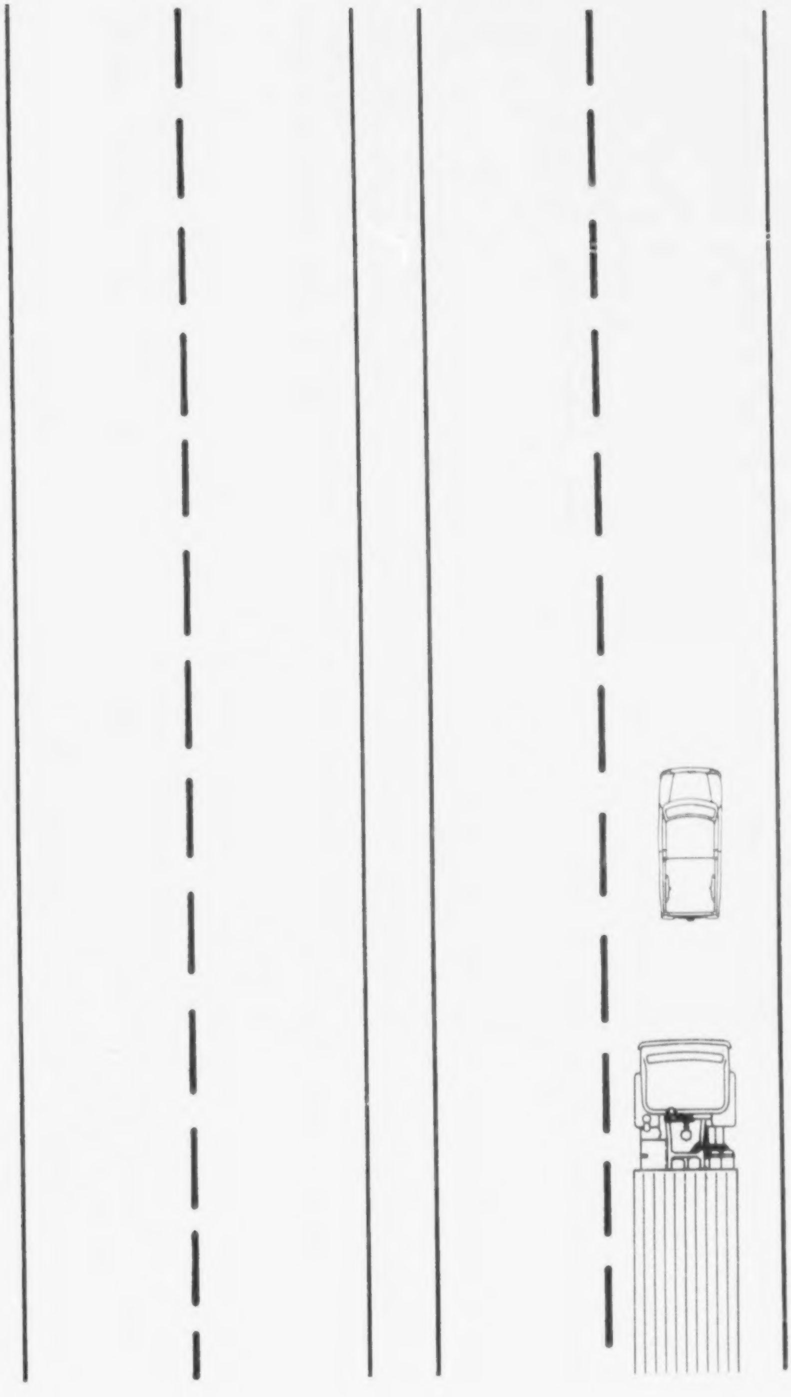
Review Safe Operating Procedures Checklist)located at end of next lesson).

Questions

Allow time for any questions students may have concerning either the maneuver procedures described in this lesson or concerning the way in which Lesson 2 will be performed.

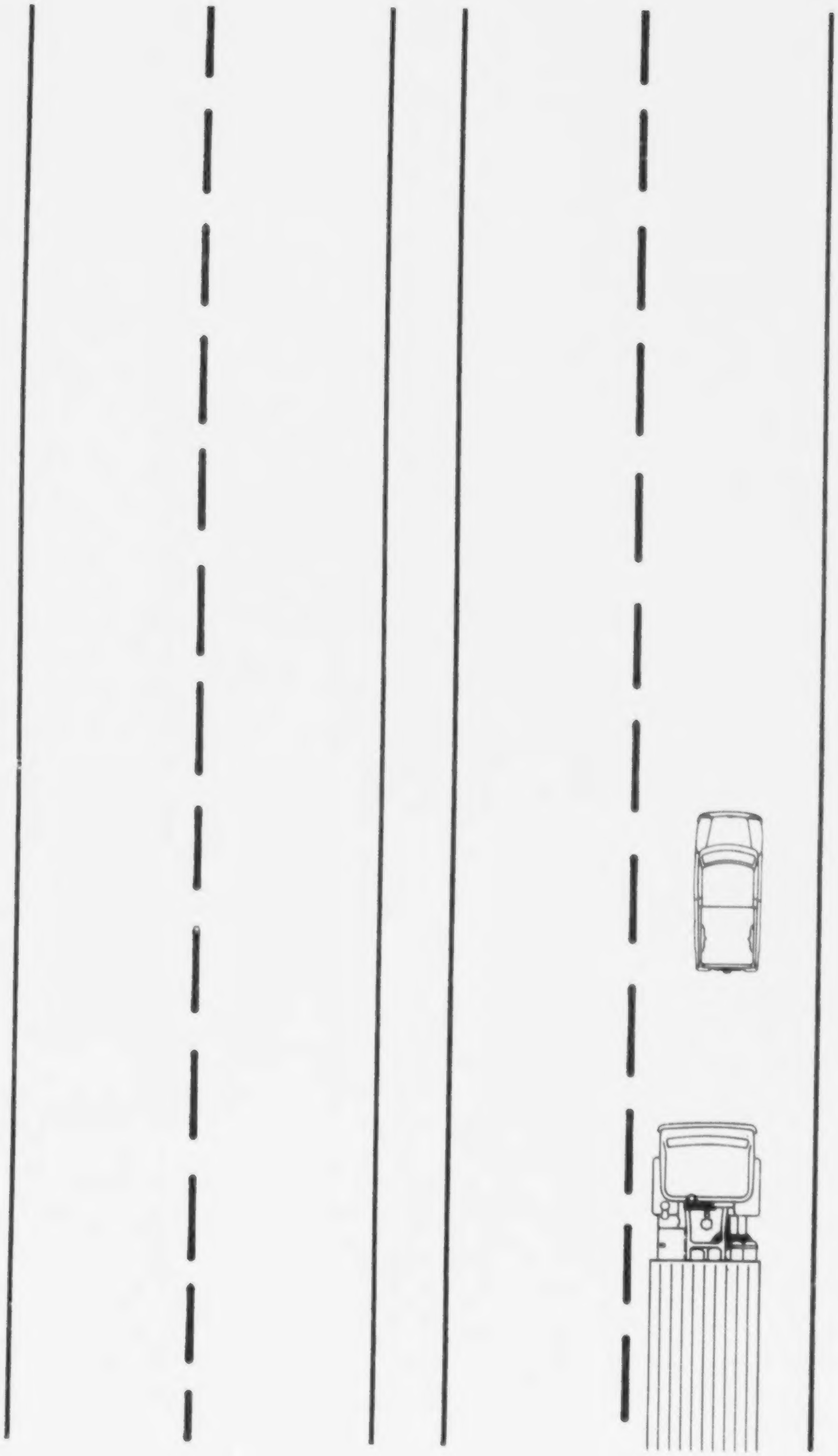
Visual 1

Lane Changing



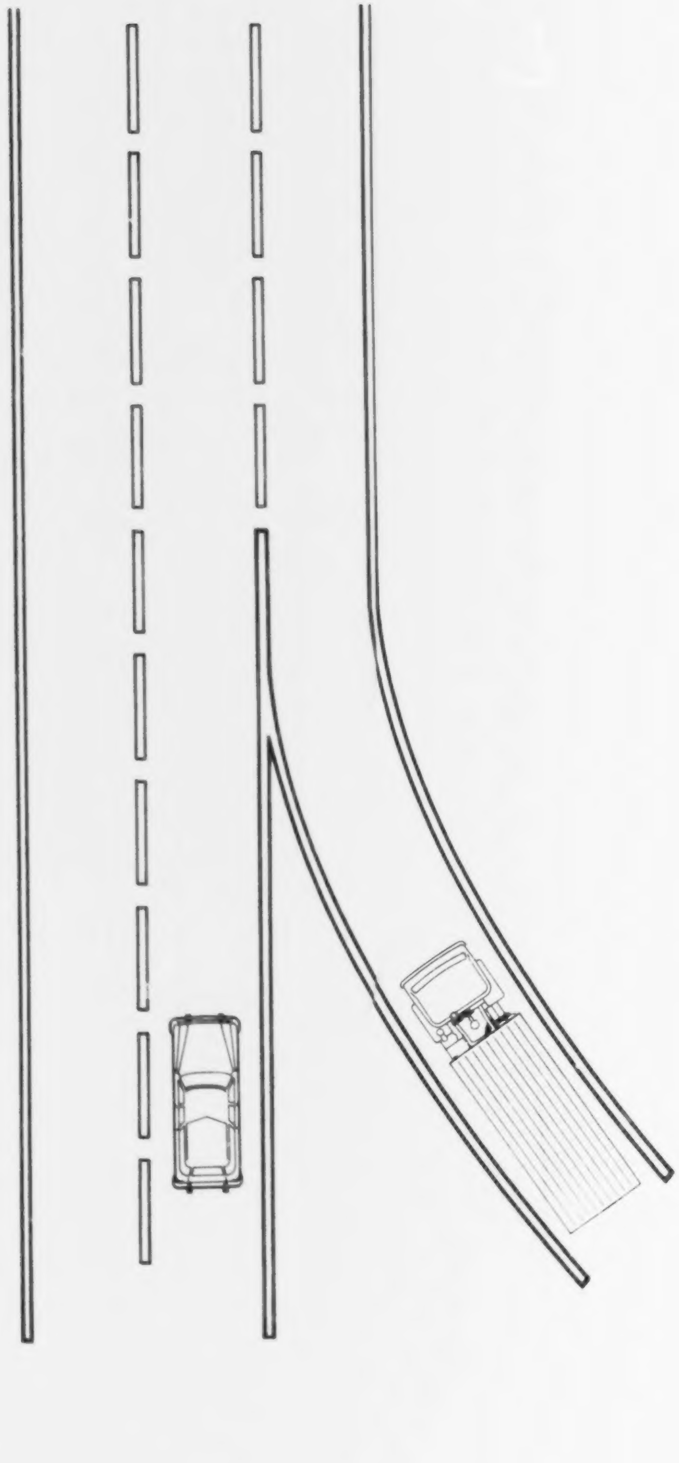
Visual 2

Passing



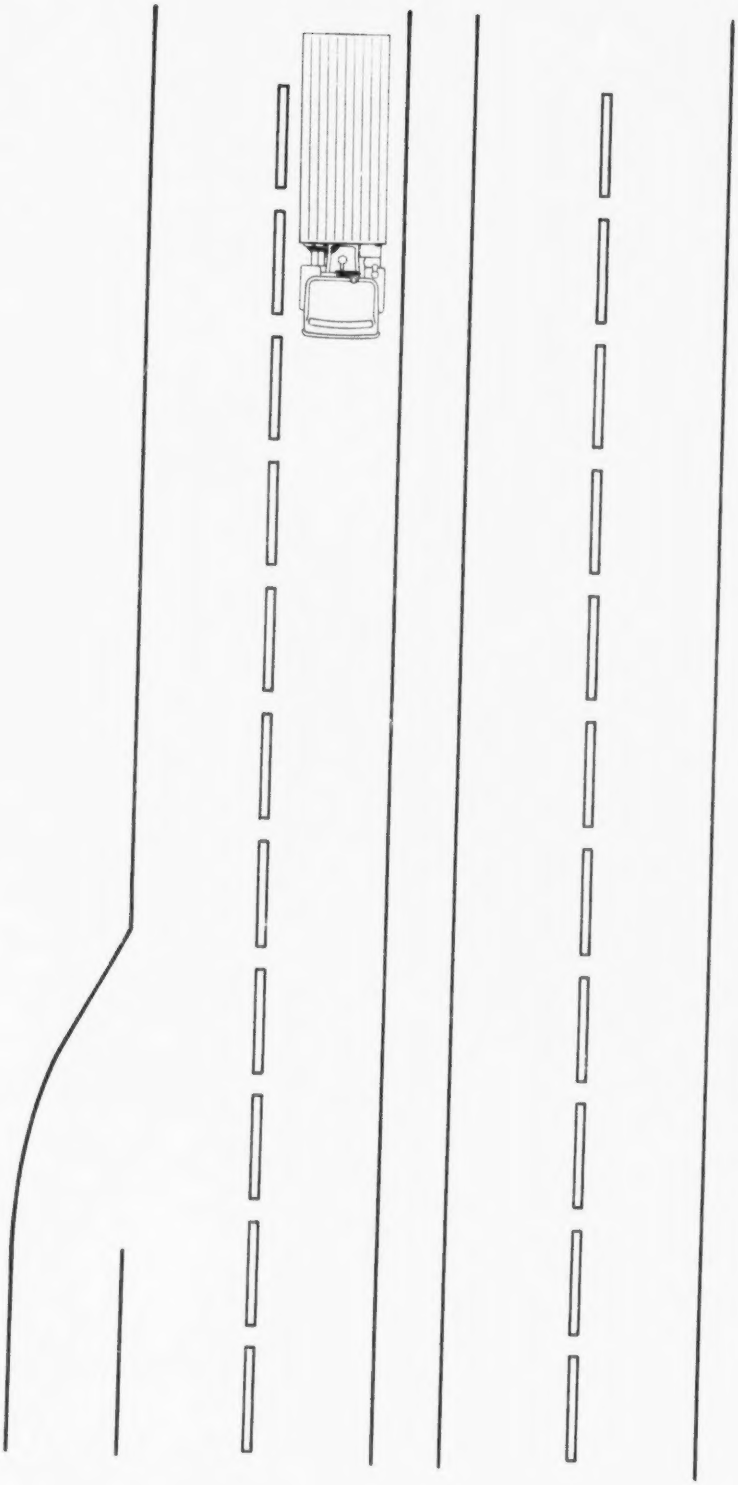
Visual 3

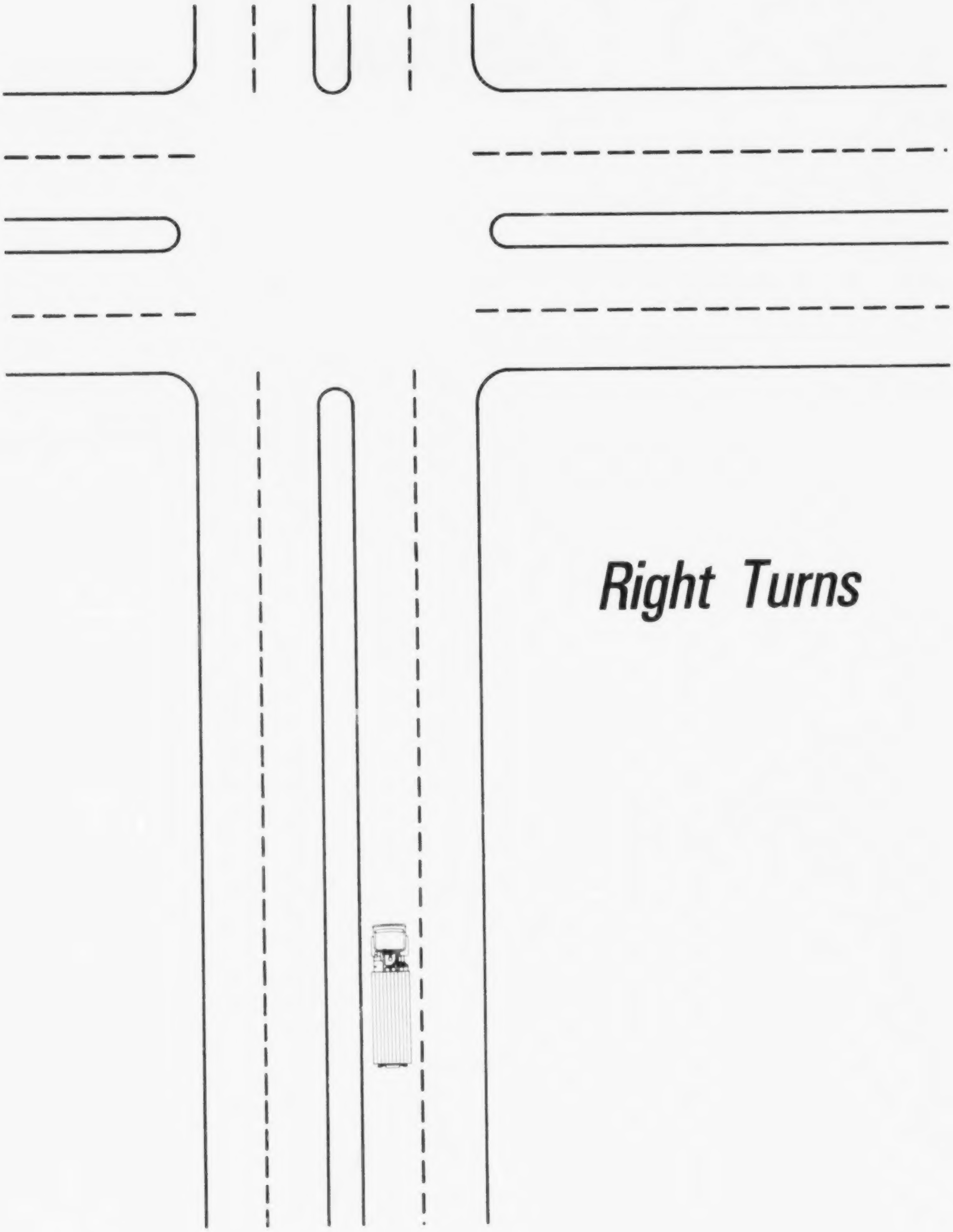
Merging



Visual 4

Exiting

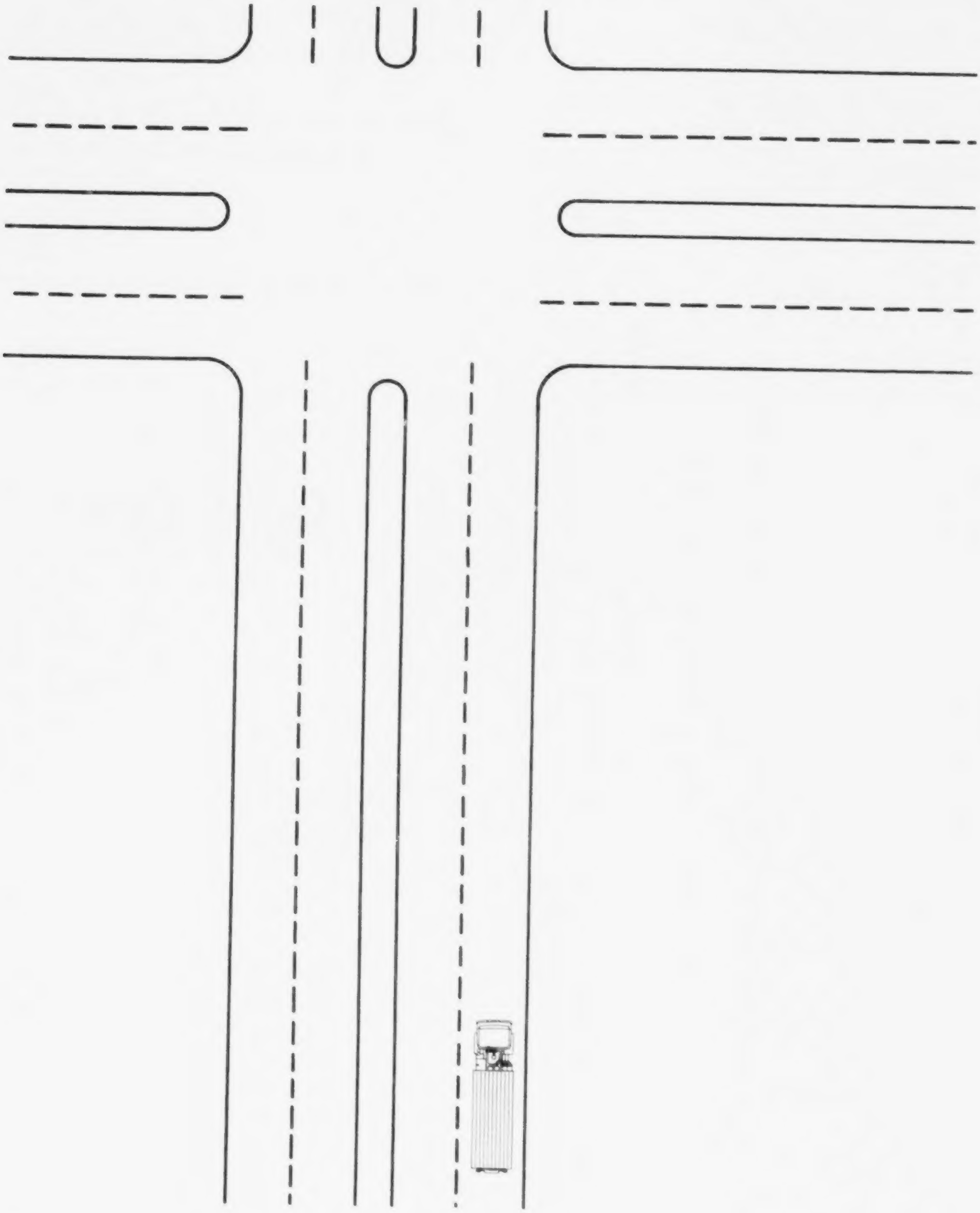




Right Turns

Visual 6

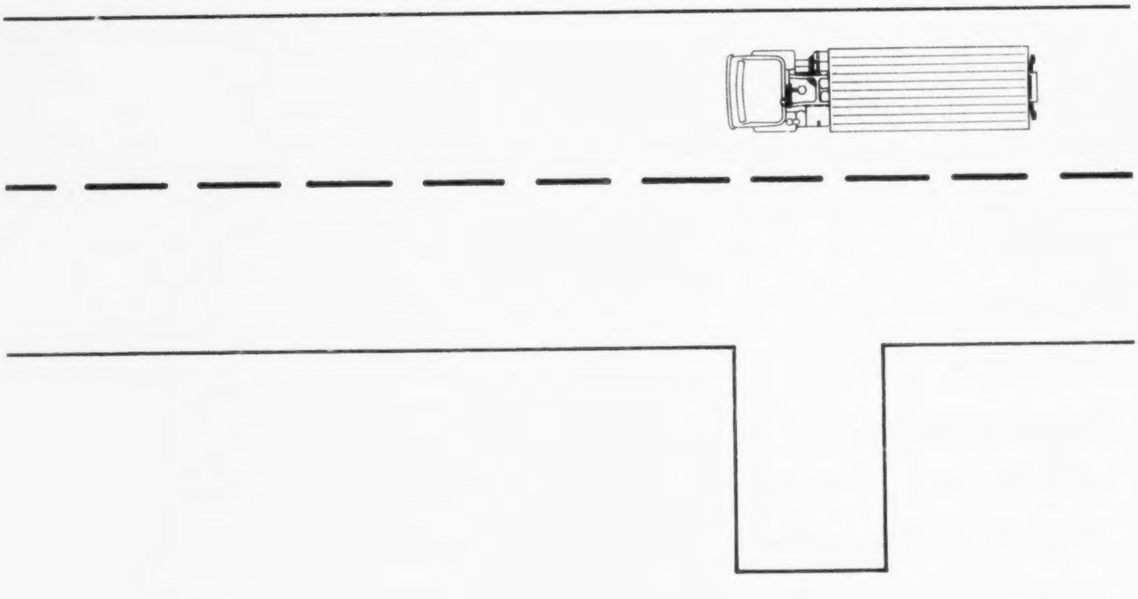
Left Turns



Visual 7

Parking Procedure

Alley Dock



LESSON 2 PRACTICE IN SAFE OPERATION (STREET)

Overview

Time Allotted: 70 hours 30 minutes

Prerequisites: Unit 2.7, Lesson 1

Students may enter this lesson upon completion of Unit 2.7, Lesson 1. However, they should complete both classroom and street lessons of Unit 3.1, Hazard Recognition, by the time the first 20 hours of this lesson have been completed in order to allow ample opportunity to develop proficiency in the recognition of hazards.

Purpose:

The purpose of this lesson is to provide students with an opportunity to (1) develop vehicle handling skills within the street environment, and (2) apply safe operating practices, including search, communication, speed management, space management, and hazard recognition. Students will go out in their usual three person teams per vehicle/instructor. With this three students to one vehicle ratio each student will be able to receive 23.5 hours of BTW time and 47 hours of observation time. It must be remembererd that the minimum required BTW time for a student to graduate is 38.5 hours of BTW time during which he/she must have driven a minimum of one-thousand (1,000) miles onstreet.

Materials

Instructional Aids

None

Student Materials

Safe Operating Procedures Checklist, in Unit 2.7 of Student Manual

Rules for Onstreet Driving, in Unit 1.1 of Student Manual

Driver's Duty Status Record (Driver's Daily Logbook) in which to log driving time/miles

Driver's License or Learner's Permit, as required in your State

Instructor Material

Safe Operating Procedures Checklist (at end of this lesson)

Clipboard and several extra copies of the Safe Operating Procedures Checklist

Equipment

See Unit 1.8, Lesson 3 for details of vehicle requirements and also review the School Administrator's Manual

Ballast or dummy cargo sufficient to achieve at least a payload of fifteen-thousand (15,000) pounds is required (a 50-60,000 pound payload is preferable).

Eye movement check mirror to be mounted on sun visor or panel above student driver's head to allow instructor and observers to monitor student dirver's eye movements

Accelerometers to measure both longitudinal acceleration (when braking) and lateral acceleration (in curves and turns - while not mandatory this is highly desirable to enable objective ratings of student's performance)

Tachographs and fuel flow (fuel economy) meters are also not mandatory but are highly recommended to improve instructor's quality of feedback to students and to insure maximum objectivity of student performance

Content

Activity or Topic	Approximate Time
1. APPLICATION OF SAFE OPERATING PROCEDURES	70 hours 30 minutes

1. APPLICATION OF SAFE OPERATING PROCEDURES (70 hours 30 minutes)

Purpose

The purpose of this lesson is to provide student instruction and practice sufficient to allow them to develop their driving skills to the level needed to pass the Road Test portion of the Final Examination Test Battery.

Routes

During this lesson, student should be exposed to the fullest possible range of operating conditions, including the following:

Roads--Students should operate over urban and suburban streets, rural highways, and expressways.

Traffic Conditions--During the first 5-10 hours, traffic density should be relatively low. However, as the lesson continues, students should be exposed to increasingly heavy traffic, including (1) rush hour traffic* on main arteries, and (2) midday traffic in urban areas.

Environment--Following the completion of Unit 2.5, students should begin driving under the fullest possible range of environmental conditions.

- At least 16 of the 70 hours 30 minutes should involve driving at night. An overnight trip is the easiest way to accomplish this.
- Operating on snow or ice, where safe, should be encouraged after 20 or more hours of onstreet operation.
- Weather conditions that are so hazardous as to cause discontinuation of normal tractor-trailer operation should also result in a halt to your school's onstreet training.
- If offstreet areas are available, they should be utilized during extremely bad weather to provide practice in maneuvering under conditions of limited traction.

Length of Routes--There is no limit to the length of routes in onstreet lesson of this unit. However, since it is difficult to maintain the level of attention required for profitable instruction in lengthly periods of street operation, it is generally desirable that onstreet sessions be alternated with classroom or range instruction in periods of 4 hours each, i.e., 4 hours maximum time onstreet.

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* While students should have an opportunity to experience driving in very dense traffic, not much time should be devoted to it as it doesn't provide much opportunity for learning.

During the final 20 hours, longer trips are needed so that students can experience the lengthy behind-the-wheel stints that they will encounter on the job, and gain exposure to driving situations that are not available within the area of the school, e.g., mountain driving, heavily industrialized areas, tunnels or expressways.

Directions

The general procedures for street lessons, as listed in the Introduction, should be employed with the following exceptions:

1. The student checklist need be used only for the first 10-15 hours, thereafter students should be sufficiently familiar with the full range of vehicle handling and safe operating procedures as to make use of a checklist unnecessary. Moreover, it would be difficult to sustain use of a checklist over the full 70 hours 30 minutes of onstreet driving.

2. When not using a checklist to remind them of driver errors, instructor and observers should critique fellow student's performance while they are driving. By this time, the drivers' vehicle handling skills should be sufficiently developed to permit them to listen to the instructor and observer commentary without adverse affect upon their driving.

3. In any trip over 12 hours, the sleeper berth must be free to allow students to obtain necessary rest. No more than a two-to-one student-teacher ratio will be possible.

4. Extreme care must be exercised to make sure that this lesson does not degenerate into "joyriding" sessions. Without effort by the instructor to keep observers involved, they will not remain actively learning. And, if they are not learning, there is no point in their being in school.

5. During the final 10 hours (where State laws permit), students who are deemed to be qualified by the instructor may operate "solo" provided the condition described in solo operation in the General Instructions section have been met.

6. Anytime during the final 4 hours of this session may be utilized to conduct the road test portion of the Final Examinations Test Battery.

Observations

The driver performance observed in this lesson should include the total range of behavior dealt with in all other street lessons (Units 1.8, 2.1, 2.2, 2.4, 2.5, 3.1). These performances are listed, by category, on the instructor and student checklists. If any of the entries are unclear, refer to the corresponding street lesson plan for an explanation.

UNIT 2.7 SAFE OPERATING PROCEDURES CHECKLIST

If a driver makes a driving error in one of the categories below, place a tally mark in the box.

	DRIVER		
BASIC CONTROL	#1	#2	#3
Acceleration			
Braking			
Stopping			
Upshifting			
Downshifting			
Uphill Operation			
Downhill Operation			
Speed Adjustment/Curves			
Lane-Keeping/Straight			
Lane-Keeping/Turns			
Lane-Keeping/Curves			

	DRIVER		
VISUAL SEARCH	#1	#2	#3
Distance Scanning			
Turn Path Search			
Roadside Scanning			
Blind Intersect., Priv.			
Blind Intersect., Burd.			
Mirror Usage, General			
Mirror Usage, Slowing			
Mirror Usage, Lane Ch.			
Mirror Usage, Merge			
Positioning, Merge			

		DRIVER		
COMMUNICATION		#1	#2	#3
Signaling Turns:	None			
	Late			
	Early			
Lane Changing:	None			
	Late			
	Inappropriate			
	Position			
Canceling:	Late			
	Early			
Flashers				
Brake Lights				
Use of Horn:	Insufficient			
	Improper			
Interpreting Communications	Receiving			
	Misinterpreting			

	DRIVER		
NIGHT OPERATION	#1	#2	#3
Lights/High Beam			
Lights/Dimming			
Speed Adjustment			
Following Distance			
Gap Selection			

	DRIVER		
SPACE MANAGEMENT	#1	#2	#3
Separation Following Distance			
Lateral Separation			
Passing Distance			
Overhead Clearance			
Lane Use Upgrade			
Multi-lane Roads			
Cross Streets			
Right Turn			
Left Turn			
Multi-lane Turns			
Gaps Too Close			
Too Far			
Merging Barging			
Stopping			
Alignment			
Traffic Adjustments			
Compromising			
Adjacent Operation			

	DRIVER		
TRAFFIC LAWS	#1	#2	#3
Speed Limit			
Sign or Signal			
Other			

SECTION 3
ADVANCED OPERATING PRACTICES

SECTION 3
ADVANCED OPERATING PRACTICES

This section attempts to build the advanced skills required in handling potential dangerous situations, skills that can only be acquired after those involved in basic control of the vehicle have been mastered. The units making up this section are

Unit 3.1 Hazard Perception--To enable students to recognize the potential dangers in the driving environment in order to be able to respond to them before they become emergencies.

Unit 3.2 Emergency Maneuvers--To enable the students to carry out appropriate responses when faced with emergencies.

Unit 3.3 Skid Control and Recovery--To develop student ability in control of and recovery from skids.

Attaining the objectives of the units in this section requires the development of advanced student skills in such areas as

- Hazard Perception
  - Road characteristics
  - Obstructions to visibility
  - Clues provided by other road users that spell danger
  - How to defend against the necessity for taking emergency maneuvers
- Emergency Maneuvers
  - When hazard recognition has been delayed what emergency options are available
  - How to properly execute the emergency options
  - Understanding the vehicle's and the driver's limitations
- Skid Control (Prevention) and Recovery
  - What causes skidding
  - How to prevent skids
  - How to recover from a skid

The skills involved in hazard recognition are primarily perceptual, while those involved in the handling of emergencies and skids are primarily manipulative. Neither can be developed until students have learned basic control of the vehicle to the point where they can drive without having to think about everything they do.

In past years, many truck driver training schools have taken the position that students cannot be taught these so called advanced driver skills until such time as they have had at least several months, or even years experience. What then, is that exstudent (now novice driver) to do when suddenly confronted with one of these situations while "awaiting his time" to return for the advanced training? Of all classes of drivers, the novice driver has the most urgent need for so-called "advanced" and or "emegency" skills since accident data shows that it is the very same novice driver, who lacking experience (and in this case training) who is most apt to become involved in situations requiring these skills. To graduate students without benefit of such training is to do them and all other road users a great disservice, let alone the grave risks involved.

Those who would insist that such training cannot be successfully given and/or learned by students have but to look at schools both within the country and overseas which have been doing this with a great degree of succcess. They have conclusively demonstrated that advanced driving skills can be successfully taught under properly controlled conditions, to those students who have already mastered routine driving skills. Another advantage of providing such instruction is that students quickly learn to understand the limitations of both their vehicles and themselves. This quickly engenders the "respect" that will keep them (as novice drivers) from taking any unnecessary chances, or allowing their attention to drift while behind-the-wheel.

Training in advanced skills admittedly does not come cheaply. It requires highly trained, professionally competent, instructors; good vehicles, properly equipped with adequate safety devices; and an adequate amount of space to construct proper faciliites, that provide adequate safeguards. However, it is well worth the expense in terms of reduced loss of life, limb and property, and is something that is owed to the student.

UNIT 3.1
HAZARD PERCEPTION

UNIT 3.1 HAZARD PERCEPTION

PURPOSE

The purpose of this unit is to enable students to recognize the potential dangers in the driving environment and respond before they become emergency situations.

OBJECTIVES

Performance Objectives

Students must be able to identify road conditions and other road users that are a potential threat to the safety of the tractor-trailer driver.

Knowledge Objectives

Students must know

- the visible characteristics of road conditions that present a hazard to safe operation, including slippery, soft, sloping, or uneven surfaces, debris, dangerous curves, obstructions to visibility, and location where there are likely to be strong cross winds.
- the characteristics of other road users (drivers or pedestrians) that make them potentially dangerous, including obstructed vision, distraction, confusion, impatience, impairment, and low speed.
- activities of other road users that provide clues to potential danger, including head and body movement, vehicle movement, and conflict situations.

Skill Objective

Students must be able to perceive immediately a potential threat from visible characteristics and actions of other road users and initiate prompt defensive or evasive action.

Attitude Objectives

Students must believe that

- most hazards can be detected in time to avoid a collision.
- serious hazards are encountered frequently enough to require constant attention of the driver.
- any delay in responding to a perceived hazardous situation can result in an accident.

LESSONS

Lesson 1.	Recognizing Hazards (Classroom)	1 hour 30 minutes
Lesson 2.	Application of Hazard Recognition (Street)	6 hours

LESSON 1 RECOGNIZING HAZARDS (CLASSROOM)

Overview

Time Allotted: 1 hour 30 minutes

Prerequisites: Unit 2.7 Lesson 1

Purpose:

The purpose of this lesson is to acquaint students with the nature of hazards and clues to recognizing them. The instructor will describe and exhibit graphic illustrations of various hazards faced by truck drivers. At the completion of the lesson, the instructor will describe commentary driving techniques appropriate to hazard recognition and provide a brief opportunity for practice in their use.

Materials

Instructional Aids

Visuals 1 - 11

Student Material

Rules for Commentary Driving: Hazard Perception, in Unit 3.1 of Student Manual

Hazard Perception Checklist (at end of Lesson 2 in this unit)

Instructor Material

Rules for Commentary Driving: Hazard Perception, in Unit 3.1 of Student Manual

Content

Activity or Topic		Approximate Time
1. IMPORTANCE OF HAZARD RECOGNITION		5 minutes
2. ROAD CHARACTERISTICS		20 minutes
3. ROAD USER CHARACTERISTICS		30 minutes
4. ROAD USER ACTIVITIES		25 minutes
5. COMMENTARY DRIVING		10 minutes
	TOTAL	1 hour 30 minutes

1. IMPORTANCE OF HAZARD RECOGNITION (5 minutes)

What is a hazard?

Any road condition or other road user (driver, cyclist, pedestrian) that presents a potential danger to safety of operation.

Actual dangers are emergencies

Emphasis upon potential danger

Visual 1 Brakelights on Exit

EXAMPLE: Car braking on exit.
Indicates indecision on the part of the driver
Car could return to highway without warning
As shown in visual, the car is a hazard
If driver of car actually cuts in front of others, it is no longer just a hazard; it is an emergency

Role of Hazard Perception

Recognition of hazard before it becomes an emergency allows driver to respond early

EXAMPLE: Truck driver can make a lane change or slow down to prevent a collision if the car suddenly returns to the highway
Early recognition allows time to check mirrors and signal lane change

Early response to a hazard minimizes danger
- Failure to recognize hazard will necessitate quick, potentially hazardous response

EXAMPLE: Truck driver who did not recognize a hazard would not have responded until car pulled back on highway
Would have necessitated sudden braking, quick lane change, or collision with car

Method of Hazard Recognition

Hazards must be recognized automatically
- Truck driver can't look at everything in the environment at the same time
- Hazards must attract driver's attention if they are to be recognized

Driver must be able to read the driving scene
- Similar to reading words
  - When we read, we recognize the words rather that just letters the mind forms letters into words
- Truck drivers must recognize hazards like words are recognized
  - The truck driver's mind must combine road and environment into perception of hazard

Learning Hazard Recognition

Students must learn clues to hazards

Experienced drivers learn through experiences
- Their own experiences
  - Close calls (near accidents)
  - Actual accident
- The experience of other drivers
  - War stories told by other drivers
  - Reports of accidents (e.g., newspapers)

This lesson will attempt to compress years of experience of others in into useful information for you
- Hazards will be described and illustrated
- Clues will be pointed out

The instruction will focus upon hazards that are not obvious
- In Visual 1, the car stopping directly in the path of the truck would be an obvious hazard
  - Any experienced driver would respond to the brake lights of a car directly ahead
  - Drivers don't need to be taught to respond to obvious hazards
- Intrepreting brake lights of vehicle in deceleration lane requires hazardous recognition skill
  - Vehicle is not a direct, obvious threat
  - Student must recognize brake lights as a clue to a hazard
    - This lesson will focus upon clues to hazards

Sources of Clues

Clues to hazards must be found in the environment

Can be classified as follows:
- Road characteristics--Those characteristics of the road shape, contour, and surface that provide clues to potential danger
- Road user characteristics--Those characteristics of pedestrians, cyclists, and other vehicles that identify them as being potentially dangerous
- Road user activity--Those specific activities of other road users that identify them as potentially dangerous

2. ROAD CHARACTERISTICS (20 minutes)

Characteristics of the road surface, shape, or contour that could adversely affect driver's ability to control the vehicle or to see clearly

Nature of Problem

Road hazards a major factor in truck accidents
- Exposure
  - Trucks have greater exposure to dangerous road conditions than cars because trucks

    - Travel many more miles per year
    - Operate under more adverse conditions
- Instability:
    - The relative instability of the tractor-trailer makes them more vulnerable to hazardous road conditions
        - Higher center of gravity
        - More easily tipped
        - Longer stopping distance
- Weight
    - Greater weight of tractor-trailer combination also makes it more vulnerable to road hazard
        - Longer stopping distances
        - Maybe even longer under adverse road conditions

Road characteristics posing hazard to trucks include:

- Surface conditions
- Shape and contour

Surface Conditions

Slippery Surfaces

- Slippery surfaces not always evident
- Drivers must be able to recognize clues of slippery surfaces

- Wet weather
    - Many surfaces more slippery than they appear
        - Grease strip
            - Oil dripping from passing vehicles
            - Particularly slippery just after it starts to rain (before oil is washed to the side of the road)
        - Painted (e.g., zebra striped area)
        - Metal
            - Railroad and trolly tracks
            - Steel construction plates
        - Timber (e.g., construction areas where vehicles travel on a temporary timber surface)
            - Dirt and clay surfaces
            - Secondary roads and yard areas
            - Particularly slippery when sprayed with oil (e.g., to keep dust down)

Visual 2 Slippery Surface Clues

Cold Weather

- Black Ice (upper left in Visual)
    - Thin, clear coating appears as "wet"
- Shadows (upper right in Visual)
    - Ice doesn't melt as fast in shade
    - Surfaces shaded by trees, buildings, etc. remain slippery longer
- Bridges (lower left in Visual)
    - Bridges will freeze faster than roadway
        - Metal and concrete tend to freeze quickly
        - Earth is slower to freeze
    - On wet days, bridge surfaces may be icy when roads are not

Hot Weather

- Asphalt--Oil may come to the surface and make it slippery
- After rain (lower right in Visual)
    - Water mixes with surface oil to reduce traction
    - Very slippery until washed away by continuing rain

Soft Surfaces

- Some surfaces are unable to bear the weight of the truck
    - Asphalt--On very hot days, asphalt on country roads may become soft
    - Construction areas
        - Service roads not constructed for heavy trucks
        - Undermined areas: septic tanks, filled-in sewer trenches
    - Shoulders--gravel shoulders particularly suspect after thaws or heavy rains will not support weight of rig could turn over

Sloping Surfaces

- The slope of road surface can greatly affect vehicle handling and safety
    - Banking
        - Proper banking resists outward (centrifigal) force in a turn
            - Helps keep the vehicle from sliding off the roadway
            - Allows turns to be taken at a somewhat higher speed
        - Hazard of inadequate banking
            - Lack of proper banking allows wheels to slide in curve (similar to slippery surfaces)
            - Vehicle can run off road, jackknife

- Hazard Clues
  - Unbanked curves--driver must recognize curves that have no banking or banked the wrong way
  - High crowned roads
  - Roads higher in the middle that at the edges
  - In a left-hand curve, a high crown becomes wrong-way banking
    - In sharp turn, can cause severe front end dip
      - Lock front wheels
      - Loss of control
    - In sharp turn, can cause severe front end dip
      - Lock front wheels
      - Loss of control
- Drop-off
  - Pavement often drops off or slopes off near edge of road
    - Rolls (tilts) trailer toward side of the road
    - Frequently causes top of trailer to strike roadside objects (signs, tree limbs)

Debris

Size of truck doesn't make debris any less hazardous

Danger

- Tires and wheel rims
  - Damage can cause tire failure
  - Can result in loss of vehicle control
- Electical and air lines
  - Debris thrown up by tires can damage or break electrical and air lines
  - Can result in loss of brakes
- Catch between duals

Hazards

- Boxes
  - Harmless looking boxes may contain heavy material capable of causing damage
  - When not moved by the wind, treat as a hazard

Rags--may contain

- Paper and cloth sacks
  - May contain cement or hard fertilizer
  - Same as hitting a rock

Uneven Surfaces

Humps in Road

- Particulary at RR crossings
- Can hang up low trailer
  - Damage under carriage
  - Tear off dolly wheels

Potholes

- When filled with water, may be deeper than they appear
- Can damage wheel rim

Shape and Contour

The shape and contour of the road can create hazards. Most common hazards result from

Curvature--sudden unexpected curves

Visibility restrictions--things that prevent the driver from seeing other road users

Crosswind areas--places where an unexpected cross wind could cause the driver to lose control of the vehicle temporarily

Visual 3 Road Shape and Contour Clues

Curvature

Hazard of curves described in Unit 2.3 (Speed Management)

Clues to curves often available

Roadside (upper left)
- Trees, power lines, buildings alongside roadside can show path
- In illustration, trees show that road continues to curve beyond the hill on the right

Distant Path (upper right)
- Road configuration can often be judged from the path ahead
- In illustration, it appears that
  - Road turns to the right, and then to the left
  - There must be a sharp turns at the bottom of the hill

Downhill Exits (lower right)
- Descending or downhill exits are particularly dangerous to trucks
  - Downgrade makes it difficult to reduce speed quickly
  - Problem aggravated by weight of truck and cargo
    - The heavier the vehicle, the more difficult it is to reduce speed on a downgrade
    - Unstable (shifting) cargo can increase the chances of a roll over accident at the bottom of the exit
- In illustration, the wall at the right is a clue that
  - The road about to be entered passes underneath the road the driver is leaving
  - The exit goes down hill to enter the new road

Weave Exits (lower left)

- The name given to the exit in which traffic exiting from the highway must weave across traffic entering the highway
- Particular problem for trucks
  - Often can't see entering vehicles along right side
  - Entering drivers looking upstream, can't see truck pull off
- In illustration, the weave interchange should provide a clue that there is an entrance ramp at the right, even though it is obscured by the hill

Visibility Restrictions

Many characteristics of the road restrict the ability to see clearly

Being able to recognize clues of restricted visibility will help drivers prepare

Tunnels
- On bright sunny day
    - Eyes adapt slowly to light change
    - Must be prepared to remove sunglasses on entering tunnels
    - Must be prepared to replace them upon leaving tunnel
    - Same effect occurs when entering a warehouse or dark alley, on a bright day
- On cold day
    - Temperature inside tunnel may be lower than outside
    - Windows and mirrors could ice up
    - Prepare by turning defroster on in advance

Hill Crests
- Sunrise or sunset
    - Expect to encounter sun glare upon cresting hill
    - Have sunglasses ready
- Nighttime
    - Glow of light indicates oncoming vehicle
    - Be prepared for headlight glare upon cresting hill
    - Use glare prevention procedures discussed in Unit 2.5--Look to the right side of the road

Crosswind Areas

On windy days, a vehicle may experience a violent crosswind when moving from protected to open area
- Cut in mountains
- Open field

Sudden crosswind can cause temporary loss of control
The absence of trees, hills, and other protection provides a clue of possible crosswind
Prepare to react with quick steering input

3. ROAD USER CHARACTERISTICS (30 minutes)

Problem

Drivers often told to drive like everyone else is nuts
- Not very practical
- Can't watch everyone and everything
- Not everyone is an incompetent driver

Must be able to recognize those road users who are giving clues that indicate they may do something hazardous

Clues to Road User Hazards

Obstructed vision--drivers who are not able to see in front
Distraction--drivers who don't see the truck and are distracted
Confusion--drivers who are too confused to notice the truck
Slow travel--drivers who are driving slowly
Impatience--drivers who are too impatient to wait for the truck to clear their path
Impairment--drivers who are too intoxicated or drowsy to drive safely

Obstructed Vision

Problem

People who can't see other road users are probably the most dangerous hazard
Not being able to see other road users, they could decide to change positions suddenly

This section will discuss clues that will help to identify the drivers whose vision is obstructed

Visual 4 Obstructed Vision Clues

EXAMPLES: Vehicles with limited visibility (upper left visual)
- Vans, loaded station wagons, cars with rear window obstructed
- Rental trucks--drivers often inexperienced with vision obstruction
- Vehicles with frosted, ice covered, or snow covered windows

Vehicles partially hidden by blind intersections (upper middle visual)
- You can see the other vehicle
- You know the other driver cannot see you

Vehicles hidden by stopped vehicle
- Vehicle turning left across stopped traffic (upper right visual)
  - Left turning driver can't see vehicles passing on right
  - Driver passing on right cannot see left-turning vehicle
- Crossing a line of stalled traffic at an intersection
  - Crossing driver cannot see vehicles traversing intersection in far lane
  - Vehicles traversing intersection in far lane can't see vehicle coming out from side street
- Height of cab does not prevent other road users from being hidden

Delivery trucks (lower left visual)
- Vision of delivery people frequently obscured by packages, vehicle doors, etc.
- Drivers of step vans, postal vehicles, and the local delivery vehicles often get out in a hurry (particularly when double parked)

Parked Vehicles (lower center)

- Occupants may get out

Clues:
- Visible movement inside vehicle
- Vehicles shakes (people moving)
- Vehicle may pull out

Clues:
- Brake/backup lights
- Exhaust
- Driver behind wheel
- Driver seen entering earlier (12-second eye lead time)
- Vehicle shakes (engine starting)

Stopped bus (lower right)
- Passengers may cross in front or behind
- Cannot see approaching truck

Slowing/stopped taxi
- Passengers often get out on street side
- Pedestrian may run out from curb

Cars backing--Driver's view to the right obscured

Pedestrians
- Walking with back to the traffic
- On rainy days
  - Hurrying: Don't look
  - Vision obscured
    - Hats
    - Umbrellas

Visual 5 Distraction Clues

Distracted Drivers

Problem

- Drivers whose attention is drawn elsewhere may not notice truck
- Noise of approaching truck could cause him to jump into truck's path
  - Whatever draws their attention may cause a sudden position change
- This section describes clues that a road user may be distracted by
- Lack of eye contact
  - Road users looking elsewhere
    - Can't see approaching truck
    - May pull directly into path
  - Positive eye contact no guarantee
    - Pedestrians/cyclists often assume truck driver will yield
    - Eye contact no good if each road user assumes the other will yield the right-of-way
- Children
  - Attention to traffic easily distracted
  - Will tend to act quickly without checking traffic
  - Children playing with one another are particularly distracted

Talkers--Drivers or pedestrians engaged in conversation

Workers
- Highway construction, road repair, utilities, etc.
    - Nature of work creates a distraction
    - Mere presence of work area or service vehicles a hazard clue
- Delivery people
    - Often distracted by loading, unloading
    - Delivery vehicle is a clue itself

Taxis--Drivers looking for passengers

Vendors
- People walk to and fro without looking
- Ice cream wagons are a particular distraction (small children)
- Presence of vendor vehicle is hazard clue

Disabled Vehicle
- Drivers changing tire, tinkering with engine often preoccupied with repair work
- Passengers often get out of vehicle
- Jacked up wheels are hazard clue themselves
- Passing drivers often distracted

Emergency Areas
- Accident scenes
    - Pedestrians and passing drivers absorbed by accident
    - People often run across road without looking
- Hospital area
    - Ambulances arriving; attendants may move in and out of the road quickly
    - Friends, relatives of patients may be following the ambulance
    - Stressful situation creates distraction

Shoppers
- People in and around shopping areas often preoccupied
    - Looking for stores
    - Looking into store windows

Visual 6 Confused Drivers

Confused Drivers

Problem

Confused road users often stop, change directions suddenly

EXAMPLES: Common clues to confusion

- Tourists (upper left visual)
    - Particularly hazardous near decision points
        - Interchanges
        - Complex intersection

- Clues
    - Car top luggage, camping trailer
    - Inside the vehicle full of luggage, recreational gear, people
    - Out-of-State license tag

- Unexplainable maneuvers (upper right visual)
  - Earlier example--car in exit lane
  - Car stopping at midblock
  - Changing lanes for no apparent reason
  - Backup lights suddenly going on

- Hesitation (lower left visual)
  - Driving very slowly
  - Frequent brake applications
  - Stopping in the middle of an intersection

- Destination seeking (lower right visual)
  - Drivers who are looking at:
    - Street signs
    - Maps
    - House numbers

Visual 7 Low Speed Clues

Low Speed

Problem

- Motorists ahead who fail to maintain normal speed are a potential hazard
- Ability to react to slow drivers may be jeopardized by
  - Difficulty in judging closure rates; don't recognize we are overtaking
  - Following too closely (we don't always maintain proper following distance)
- Recognizing a slow driver early can prevent accident

EXAMPLES: Clues that vehicles are moving slowly

- Slow moving vehicle
  - Includes all vehicles with slow speeds and slow accelerations
  - Underpowered vehicles (upper left visual)
    - Includes subcompacts, motor homes, house trailers, vehicles towing heavy loads
    - Generally slow to accelerate when they pull onto the highway
    - Lose speed going up hill
  - Farm machinery and construction machinery e.g., tractors, bulldozers (upper right visual)
  - Mopeds

"Slow moving vehicles" symbol (lower left visual)
    Vehicles characteristically slow moving are required to carry special sign
    Visible only as an orange dot at a distance

Turning vehicle (lower right visual)
    Drivers signaling a turn may slow more than expected
    Drivers starting tight turns--into alley, driveway
    Vehicles entering shopping centers--pedestrians, vehicular traffic may force a premature stop
    Vehicles turning left--may pause for oncoming vehicles

Visual 8 Impatience Clues

Impatience

Problem

Impatient drivers afraid of being hindered by truck
    View trucks as slow-moving
    Try to beat the truck

EXAMPLES: Types of impatient drivers
    Merging drivers--Cut in front of truck and then slow down quickly
    Passing drivers
        May cut off truck with premature lane change
        May slow down after completing pass
    Intersecting drivers--Pull out onto a road in front of truck to avoid being stuck behind
    Drivers who squeeze by a backing truck
        Behind the truck before it starts to back
        In front of the truck before a pull-up
        Pedestrians may also dash behind the truck
    Commercial driver vehicle
        Drivers whose job or income depends upon speed are frequently impatient in coping with obstacles to their progress
        Examples include taxi drivers, messengers services, and behind-schedule bus drivers

Visual 9 Impairment Clues

Impairment

Problem

People who drive late at night particularly likely to encounter impaired drivers
    Intoxicated drivers
    Drowsy or sleepy drivers

Clues to Possible Intoxication

- Weaving across the lane
- Leaving the road
  - Dropping right wheels onto shoulder
  - Bumping across curb in turn
- Unwarranted stopping
  - Stopping at green light
  - Waiting for stop sign to say go
- Open window in cold weather
- Erratic speed
  - Too fast
  - Too slow
  - Varying between too fast and too slow
- Talking to oneself
- Sitting bolt upright

Clues to Drowsiness

- Weaving across the lane
- Dropping right wheels onto shoulder
- Violent shaking of head

4. ROAD USER ACTIVITIES (25 minutes)

Significance of Road User Activities

- Previous section dealt with particular kinds of road users
- Any road user can be a hazard
- Clues to hazard are often seen in the activity of road users
- Types of activities
  - Driver Movement-- Suspicious head or body movement of the driver
  - Vehicle Movement--motion of the vehicle that provides a tip off to speed or direction changes
  - Pedestrians and Cyclists--activities of pedestrians or cyclists that make them candidates to become a hazard
  - Conflicts-- Road users whose impending collision with someone or something else could become a hazard to the truck driver

Visual 10 Driver/Vehicle Activity Clues

Driver Movement

Sudden movements of the driver's body may precede hazardous activity

Head Movement

Looking To The Side
- Drivers generally look in the direction they are going to turn
- Head turn therefore tip-off to possible turn

Looking Behind
- Mirror or over-the-shoulder checks indicate intended lane change
- Most readily visible in the case of motocyclists, bicyclists

Body Movement

- Drivers frequently straighten up just prior to turning
  - Brace themselves for the turn
  - To get leverage on the steering wheel
- Suggests immediate turn (possible before the next intersection)

Vehicle Movement

Anticipatory Movement

- Drivers frequently edge across lane in the direction of intended maneuver
- Lateral motion provides a tip-off to lane change or turn

Button Hooking

- Truckers are not the only ones who perform button hook turns
- Common practice
  - In tight right turns (e.g., into driveway)
  - For older drivers who have trouble turning the steering wheel
  - In certain areas of country (elg., midwest, Florida)
- Move to the left often a clue to right turn
- It's dangerous to pass car on the right when it moves left

Pedestrians/Cyclists

Pedestrians running fast, cyclists pedaling hard are a potential hazard

Moving Toward Road

- May not check traffic
  - In a hurry
  - In a game or contest
  - Attention elsewhere
- May not stop (for same reasons)

Parallel to Road

- More likely to dart into road (in a hurry, distracted)
- Able to move laterally more quickly

Visual 11 Conflict Clues

Conflicts

Nature of Conflicts

Conflict--Any vehicle that is on a collision course with an object or other road user, forcing an impending change in speed or direction, including conflicts with

- Obstructions--Roadway configurations with fixed objects in the path of the other vehicle

- Merges--Vehicles merging into the path of the other vehicle

- Intersections--Vehicles intersecting with the road user

Vehicles in conflict may have to make sudden stops or lane change
- Sudden maneuver may cause damage to trucks
- Other road user's problem becomes the trucker's problem

Being able to perceive conflicts is the most challenging aspect of hazard recognition
- The hazard results from the conflict between road users rather than the characteristics or activities of the individual road users themselves
- Recognizing conflicts requires the ability to perceive the relationship between the road users

Conflicts with Obstructions

Vehicles approaching obstruction in the path ahead

EXAMPLE: end of lane (upper left in Visual)
- Driver in right hand lane is approaching where the lane comes to an end
- Driver of other vehicle has apparently not noticed the lane is about to end
- Driver will be forced into the path of the truck
- Hazard results from conflict between inattentive driver and an obstruction (the end of the lane)

Conflicting vehicle may be coming from either direction (e.g., an oncoming vehicle may pull out to pass a stalled vehicle and enter the truck's path

Common obstructions
- End of lane (e.g., lane drop)
- Barricade
- Slow-moving traffic
- Stalled traffic
- Disabled vehicle
- Accident

Merge Conflicts

Vehicle in conflict with a merging vehicle
May be forced into driver's path

EXAMPLE: Prove a merge conflict (upper right in Visual)
Vehicle on the right is in conflict with the merging vehicle
Driver of the vehicle on the right may be forced into the path of the truck
The hazard to the truck results from a conflict between two other vehicles

Merge situations that may force a vehicle into trucker's path
- Car entering freeway
- Car pulling out from driveway or side street
- Car pulling out of parallel parking place
- Pedestrian entering street

Intersection Conflicts

Two other road users are intersecting path
May force driver into a sudden stop or position change

EXAMPLE #1: Right turning vehicle conflict with pedestrian (lower left in Visual)
Vehicle ahead is signaling a right turn
Pedestrians crossing at the intersection will force driver to stop during the turn
Truck driver may be able to see the pedestrians better than driver up ahead
Can see that vehicle ahead will probably stop suddenly
Conflict between right turning vehicle and pedestrian provides clue to hazard

EXAMPLE #2: "Blind" pedestrian-motorist conflict
Truck has stopped for the pedestrian
The pedestrian does not see the vehicle overtaking on the truck's left
Driver of the vehicle overtaking on the left does not see the pedestrian
The truck driver can recognize the hazard from the conflict between the pedestrian and the overtaking vehicle
In this case, the hazard does not involve danger to the truck driver
However, trucker can alert pedestrian and vehicle driver to stop

5. COMMENTARY DRIVING (10 minutes)

Student Checklist

Rules for Commentary Driving

Refer students to rules in their book

1. Identify any hazard, (any road condition or road user) that is a potential threat to you and to which you must respond.

2. Describe the hazard in a few words, identify it by nature and location.
   Child in the street on the left.
   Yellow Volkswagen on the right.
   Pavement in the shade of that culvert.

3. Identify in a few words what makes it a hazard.
   Is looking the other way.
   Is going to back up.
   Is likely to be very slippery.
   May be forced into my lane.

4. Identify only those hazards to which you must respond in some way. If no response is required, it is not a hazard. You do not have to describe how you are responding.

5. When there is no hazard, say nothing. You do not have to announce the absence of a hazard, e.g., "clear path."

6. In conflict situations, comment only on the vehicle in conflict with your vehicle. You do not need to comment on the situation or the third vehicle, that puts the vehicle in conflict with your vehicle.

EXAMPLES: Driver Looking to the Side

Oncoming driver may turn across my path

Anticipatory Movement

Car on right may enter my lane

Merge Conflict

Car on right may be forced into my path

Intersecting Conflict

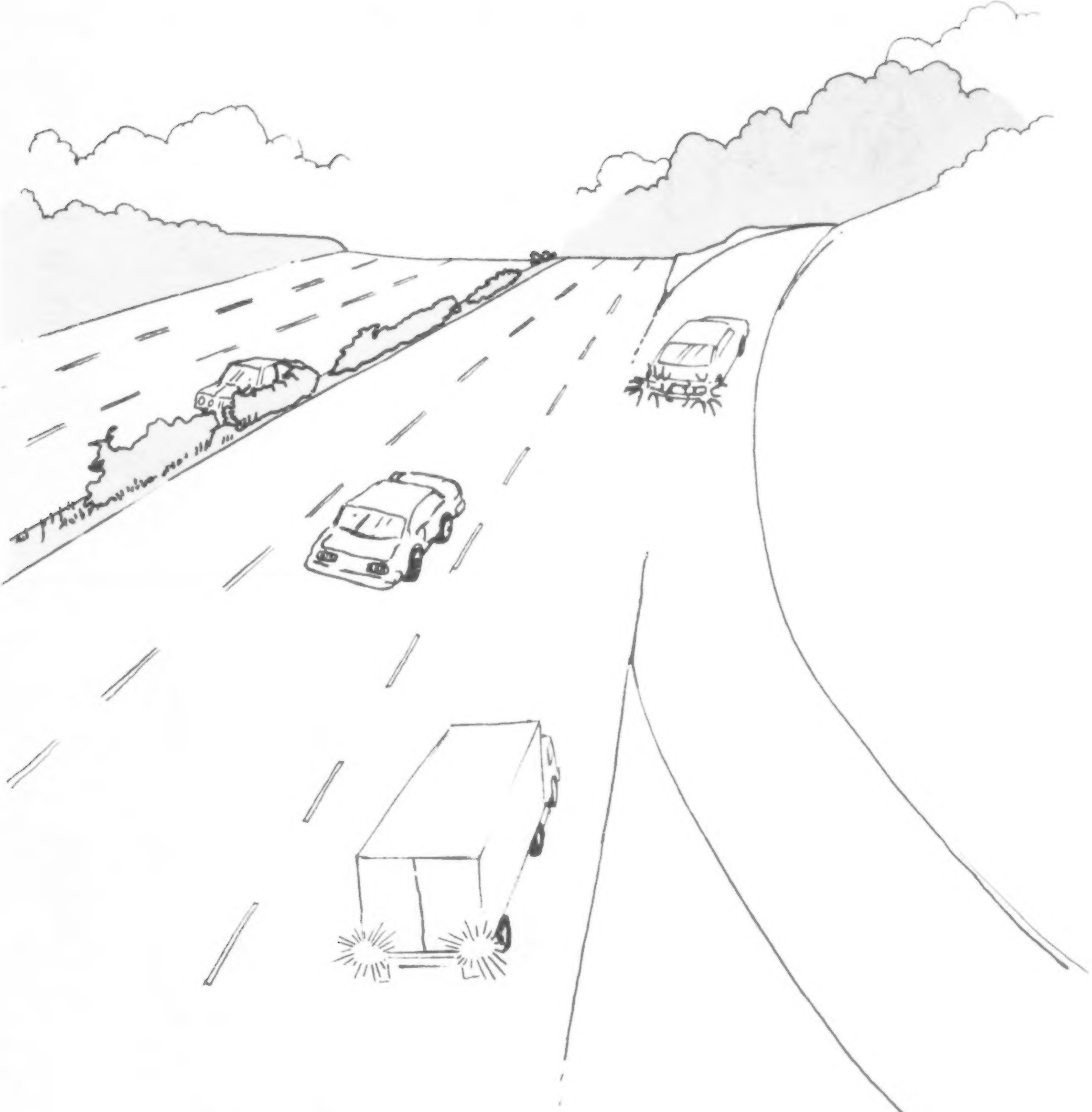
Car ahead may be forced to stop quickly

Hazard Perception Checklist

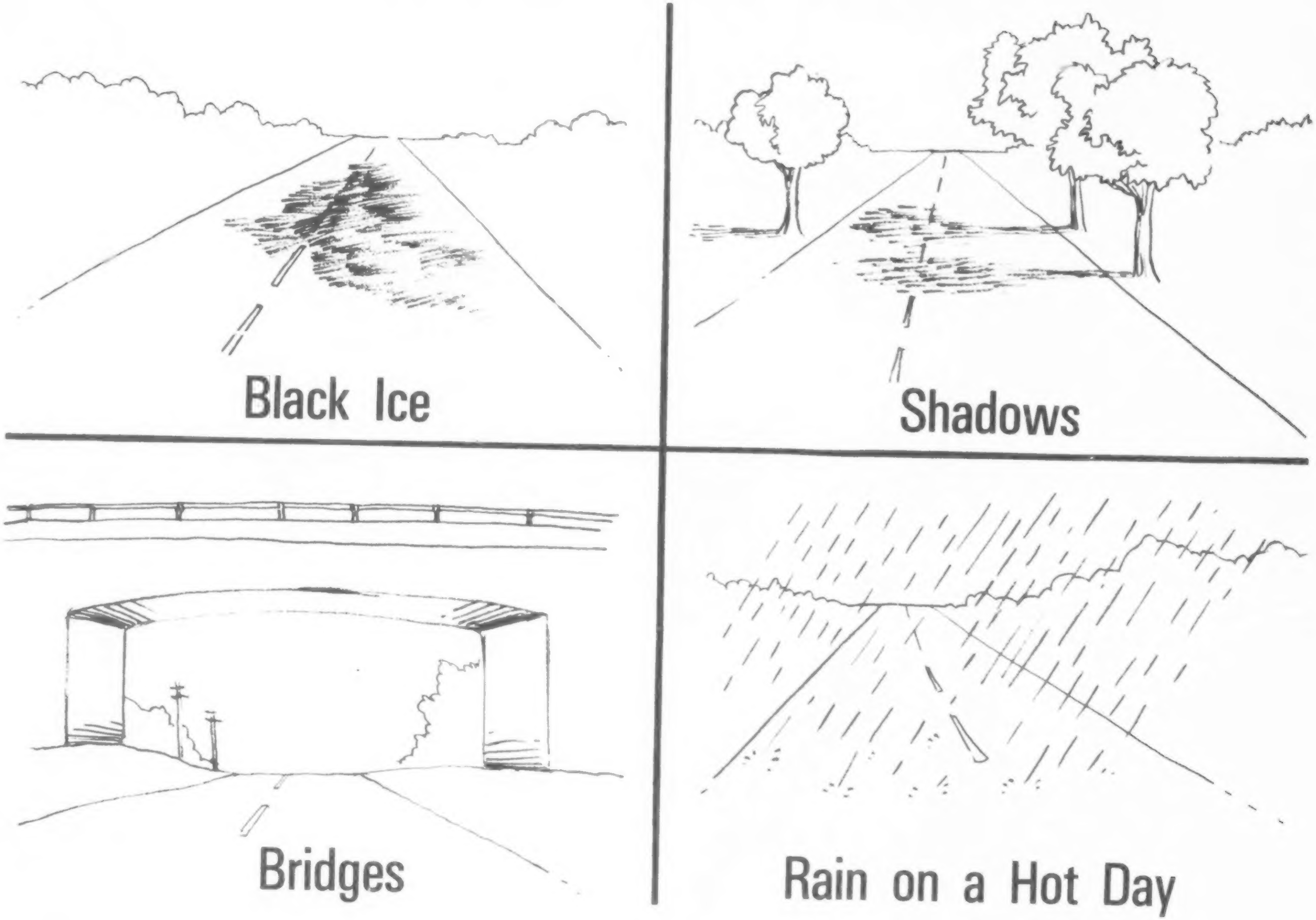
Assign students to review the Hazard Perception Checklist in Unit 3.1 of the Student Manual and become thoroughly familiar with it, prior to the start of the next lesson in this unit.

Visual 1

Brakelights on Exit



Slippery Surface Clues



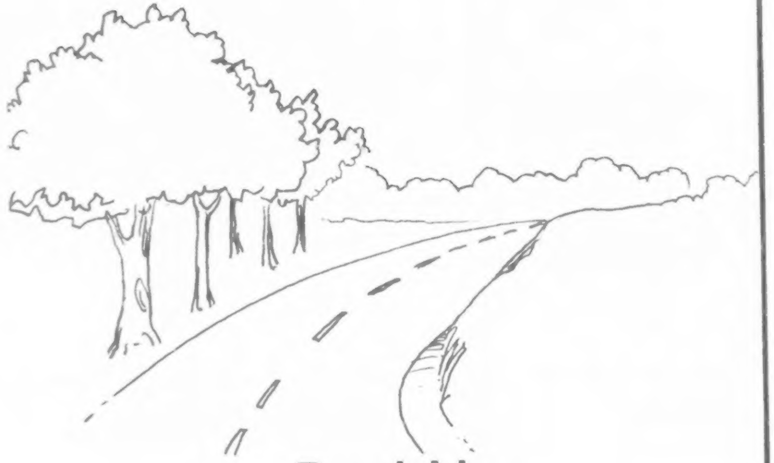
Black Ice

Shadows

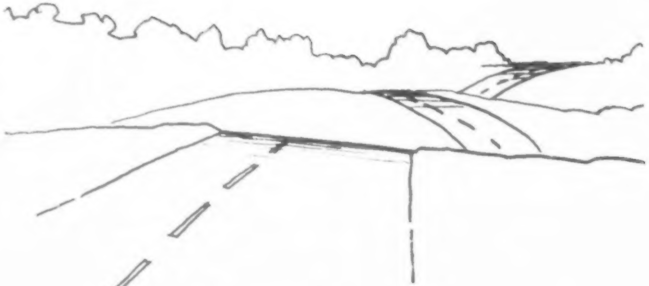
Bridges

Rain on a Hot Day

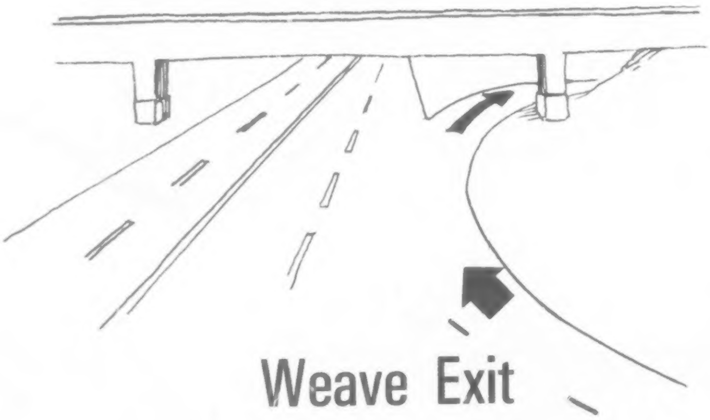
Road Shape and Contour Clues



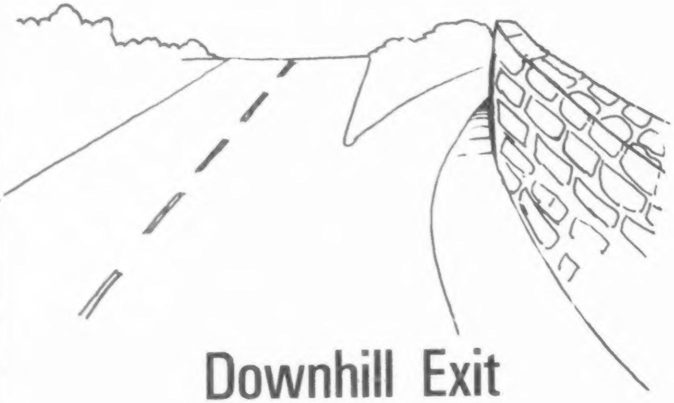
Roadside



Distant Path



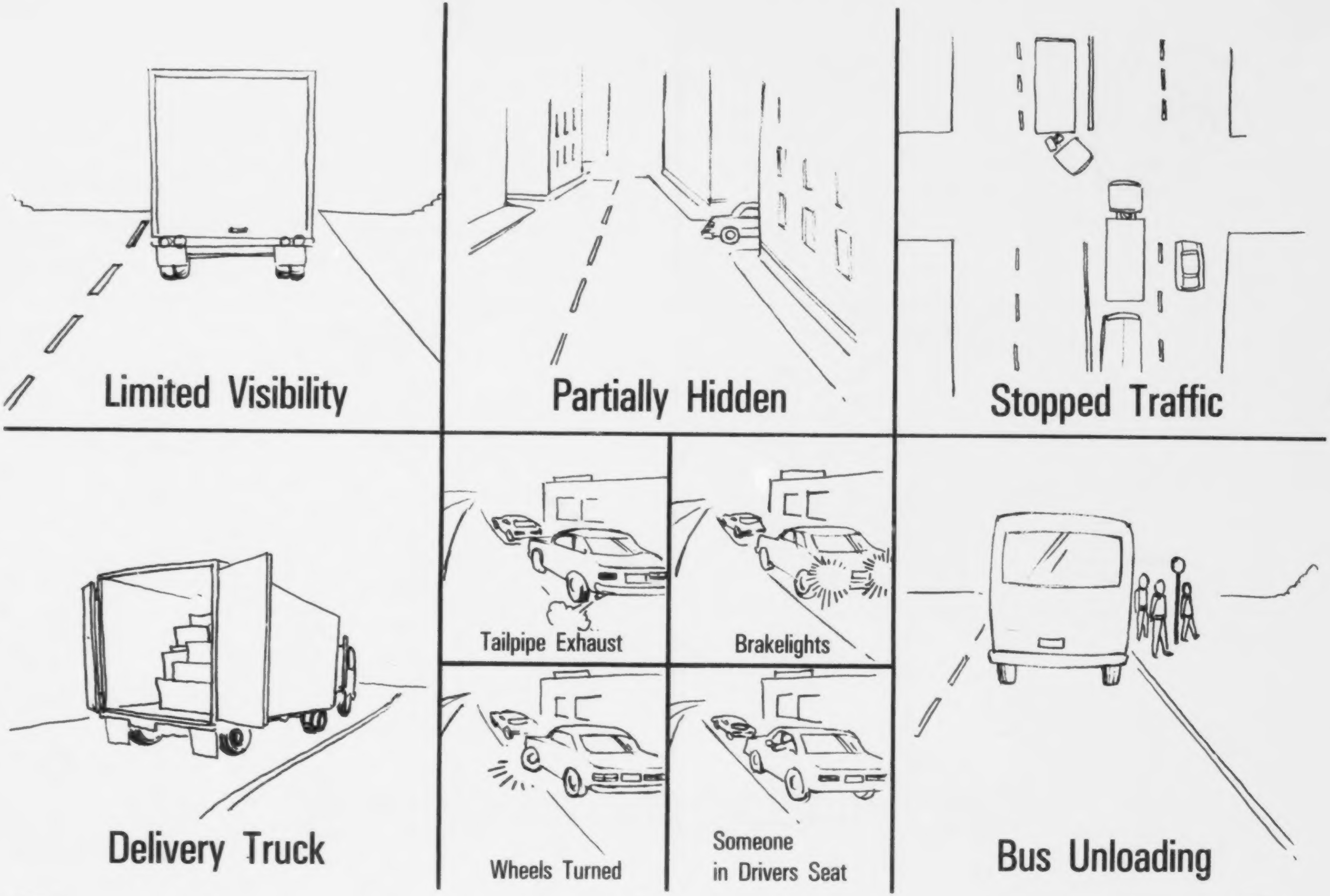
Weave Exit



Downhill Exit

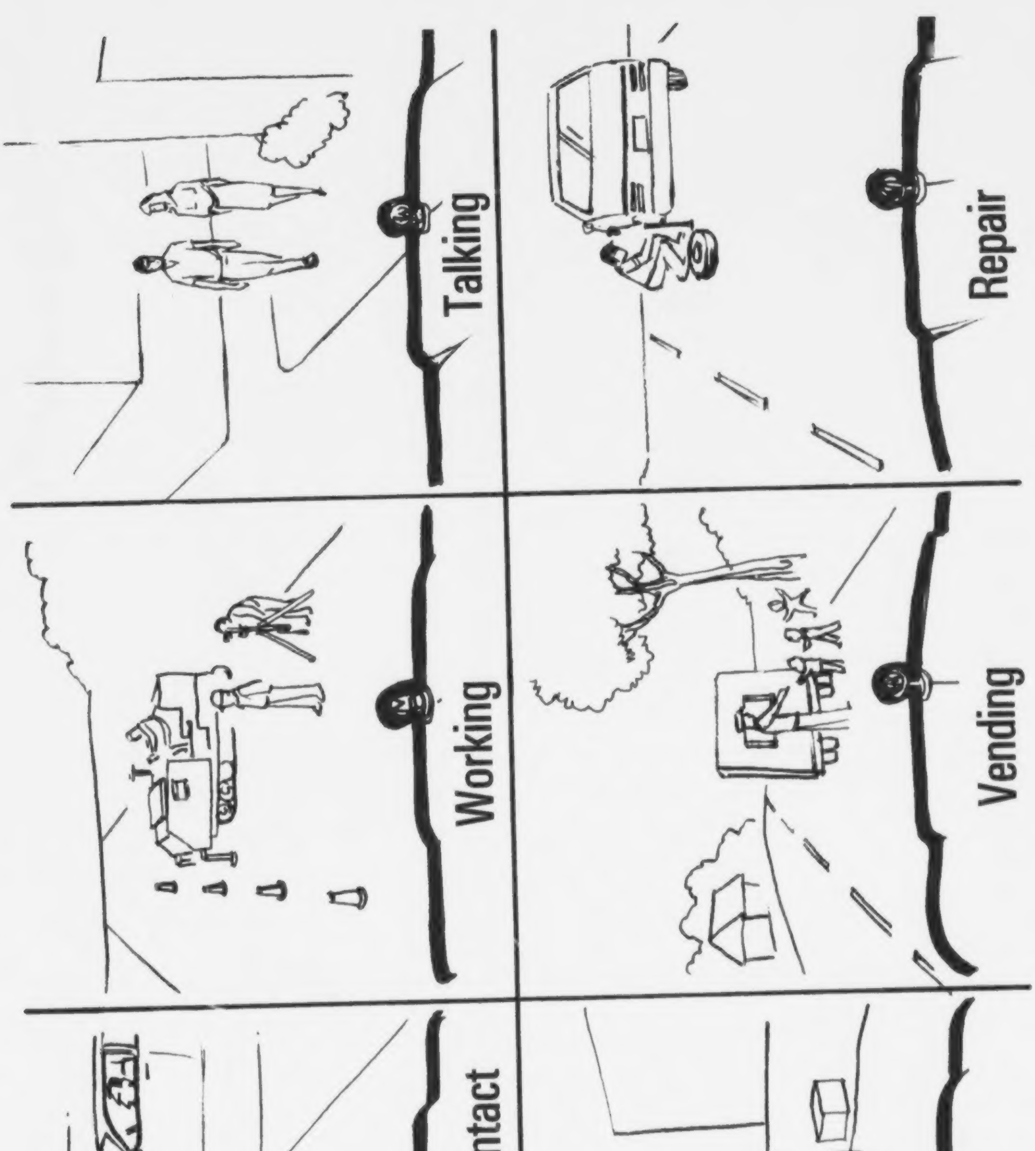
Visual 4

Obstructed Vision Clues


Limited Visibility
Partially Hidden
Stopped Traffic
Delivery Truck
Tailpipe Exhaust
Brakelights
Wheels Turned
Someone in Drivers Seat
Bus Unloading

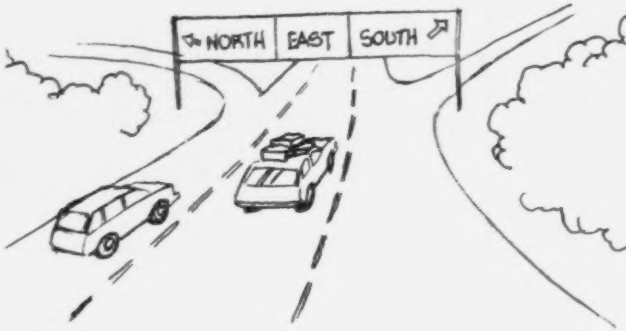
Visual 5

Distraction Clues

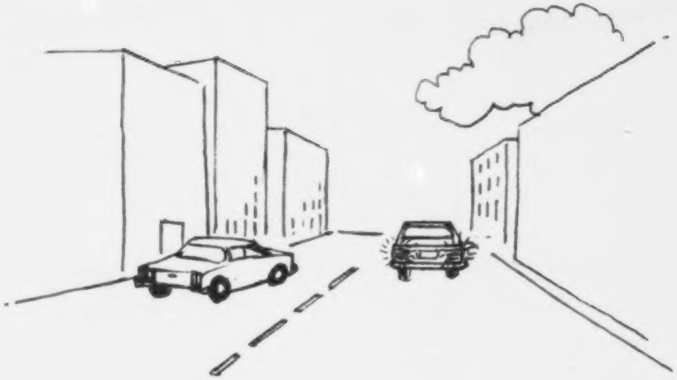

Lack of Eye Contact
Working
Talking
Delivery
Vending
Repair

READEX FICHE

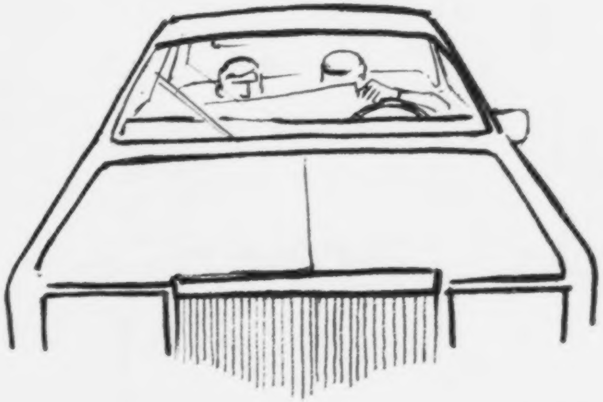
Confusion Clues


NORTH
EAST
SOUTH

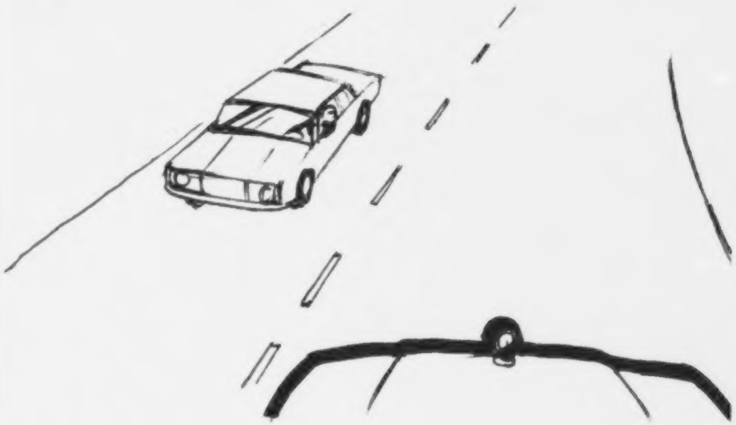
Tourists



Unexplainable Maneuvers

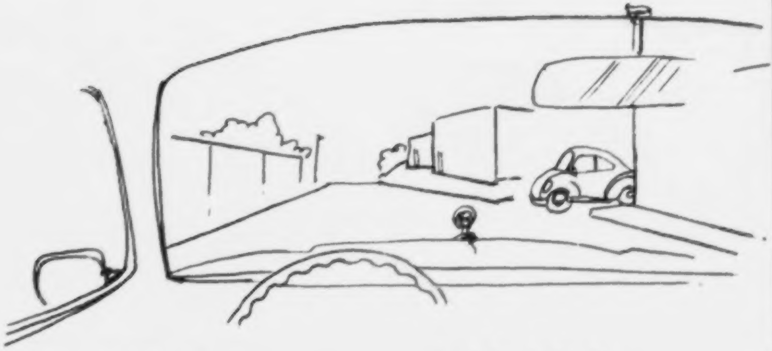


Hesitation

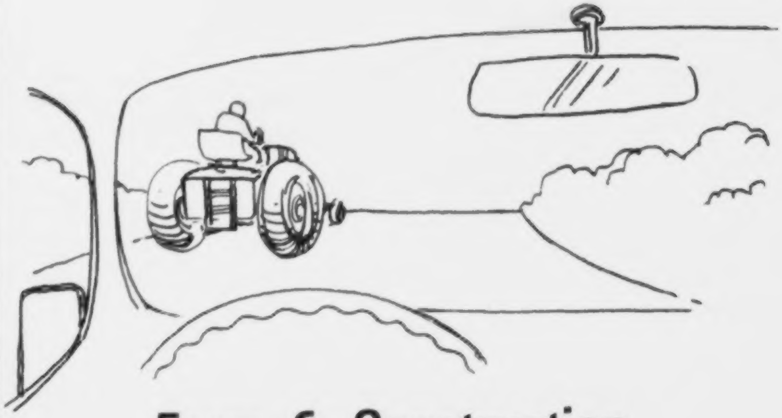


Destination Seeking

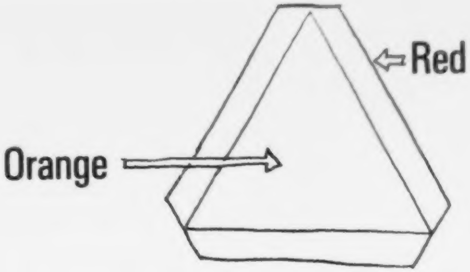
Low Speed Clues



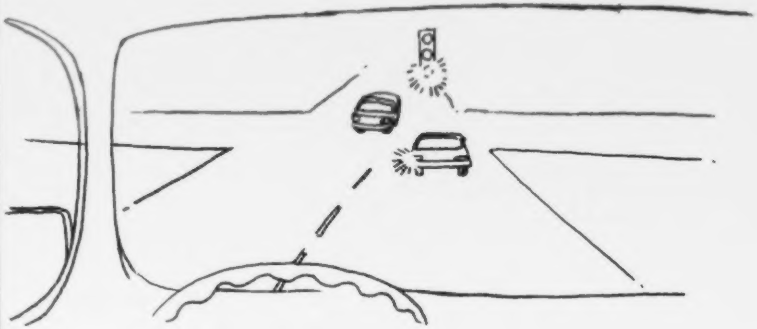
Underpowered Vehicles



Farm & Construction



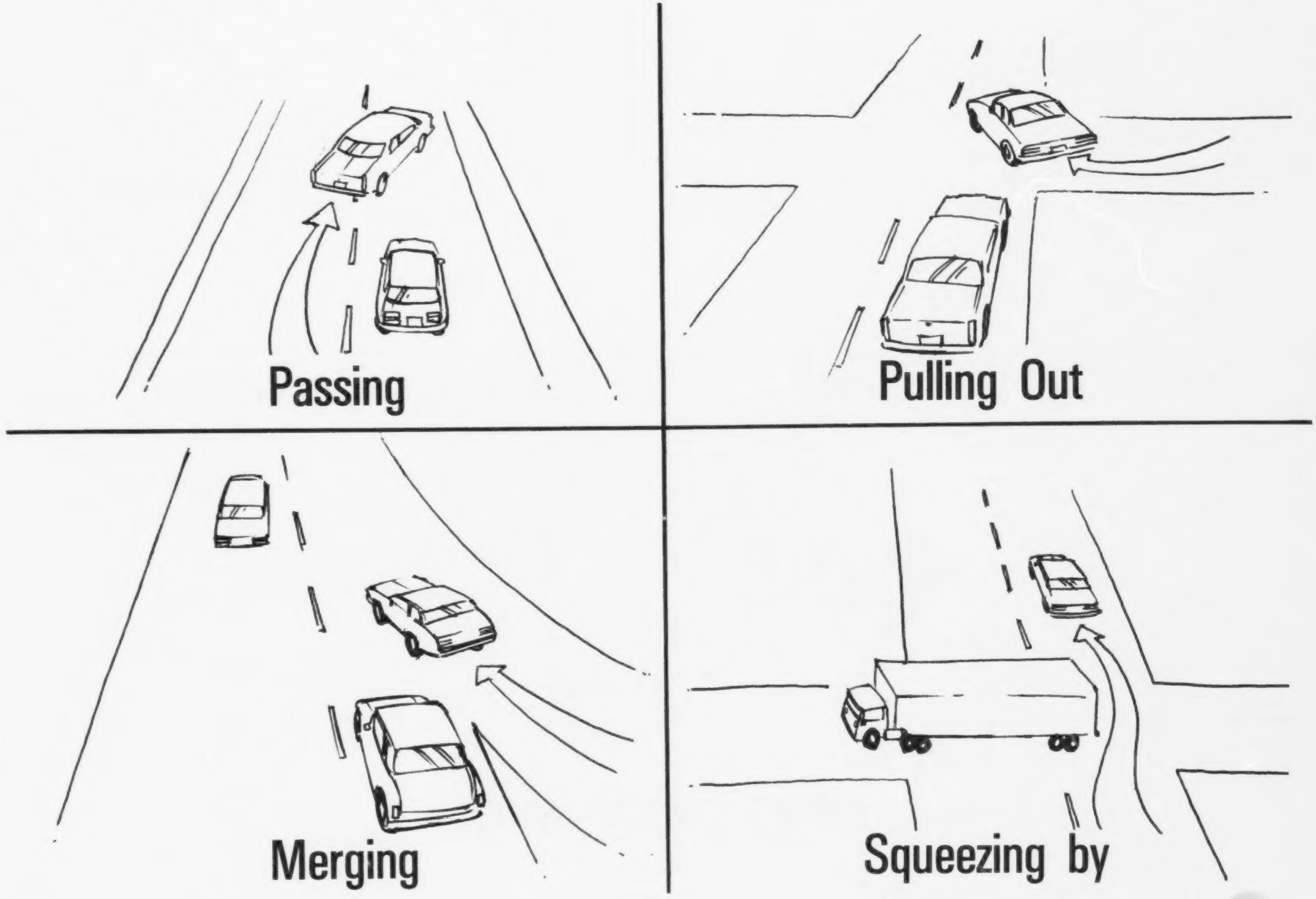
Slow Moving Vehicle Emblem



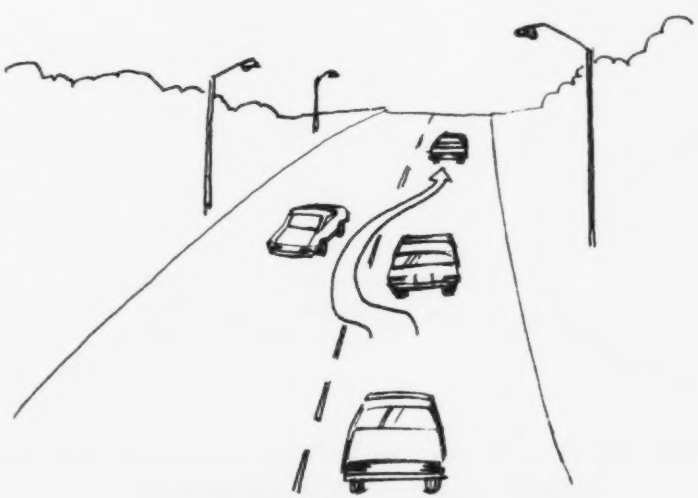
Turning Vehicle

Visual 8

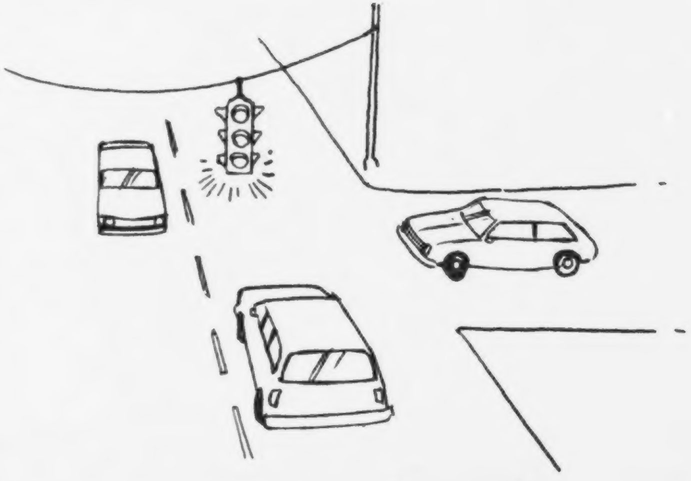
Impatient Driver Clues


Passing
Pulling Out
Merging
Squeezing by

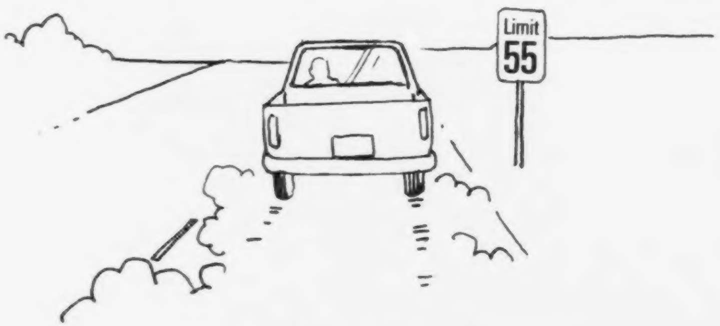
Impairment Clues



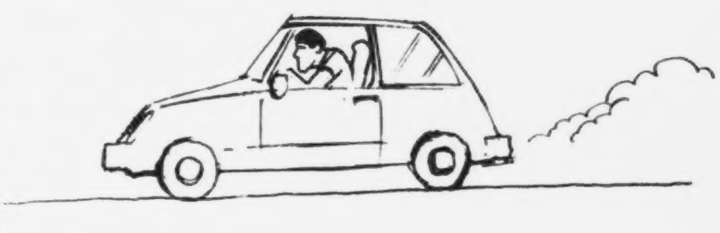
Weaving



Unnecessary Stopping

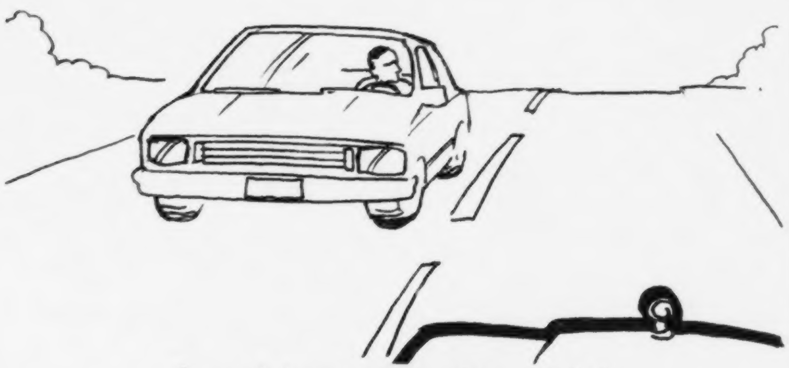


Erratic Speed

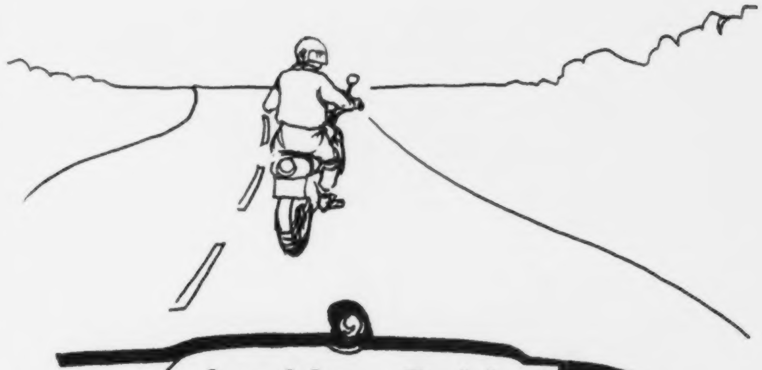


Bolt Upright

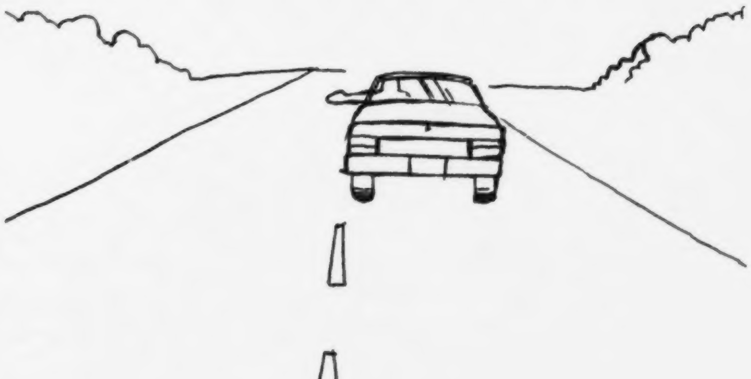
Activity Clues



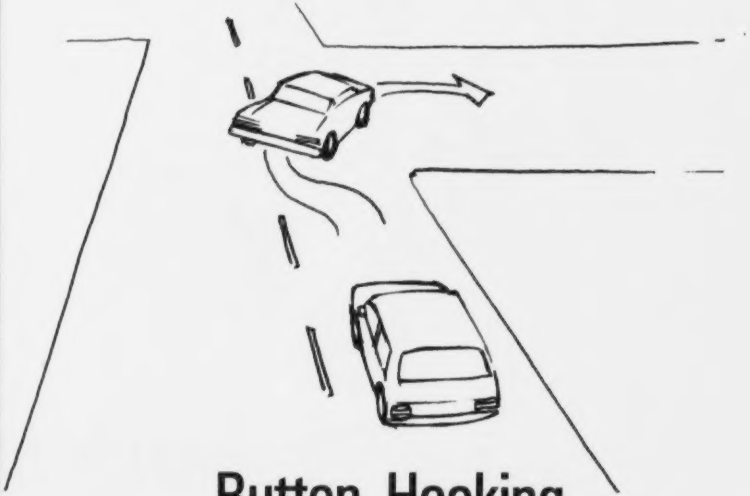
Looking to the Side



Looking Behind

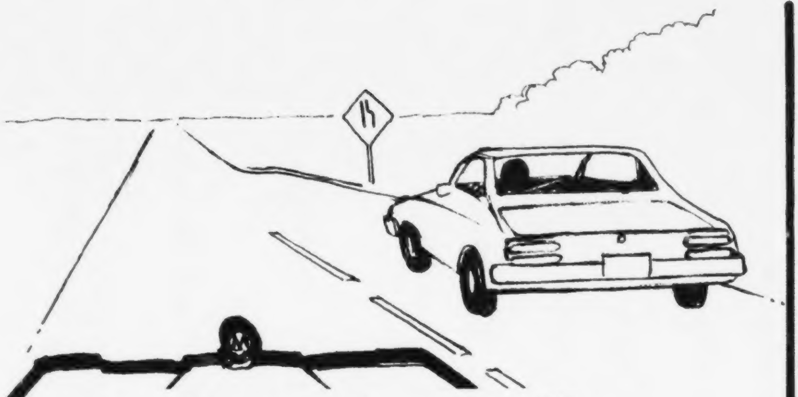


Anticipatory Movement

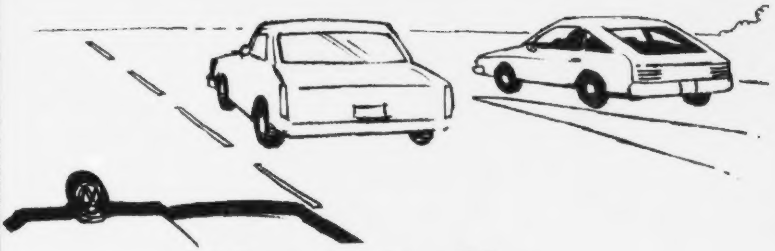


Button Hooking

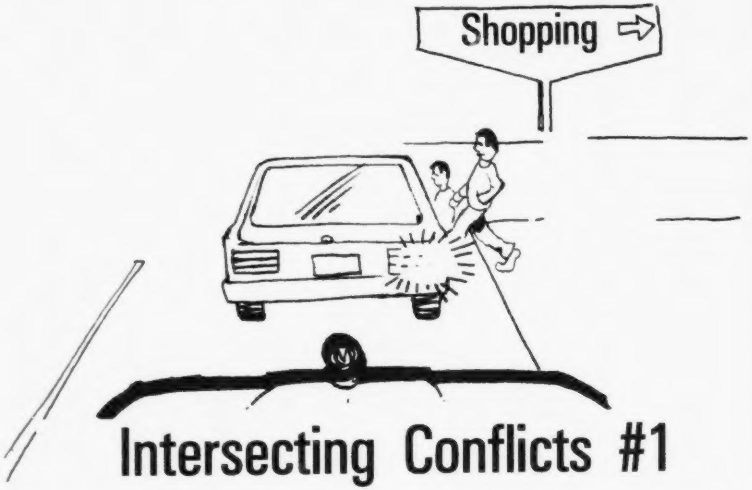
Conflict Clues



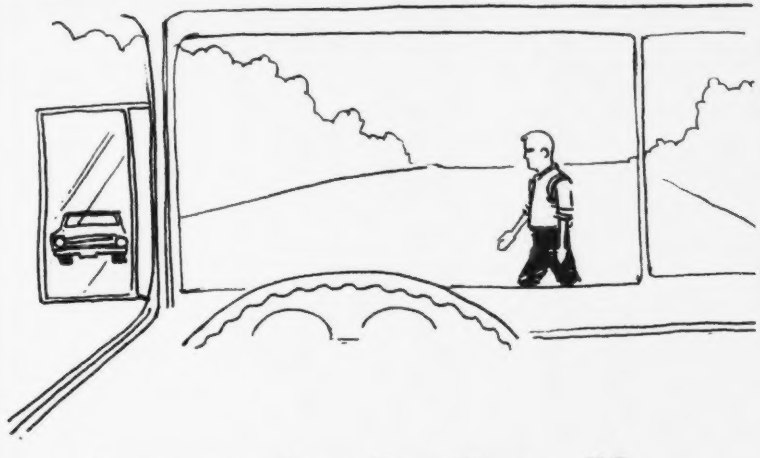
Obstruction Conflicts



Merge Conflicts



Intersecting Conflicts #1



Intersecting Conflicts #2

LESSON 2 APPLICATION OF HAZARD RECOGNITION (STREET)

Overview

Time Allotted: 6 hours

Prerequisites: 60 Hours of Unit 2.7; Unit 3.1, Lesson 1

Purpose:

The purpose of this lesson is to allow students to practice hazard recognition. Students will operate a tractor-trailer through environments characterized by common roadway and traffic hazards. The driver's recognition of hazards, as observed through the driver's oral commentary and their vehicle control responses, would be noted and recorded by the instructor and observer students. Students will go out in their usual three-person teams. Each student must receive a minimum of 2 hours of BTW time, of which one-half hour must be commentary type driving.

Materials

Instructional Aids

Video camera and video tape recroder (optional)

Student Material

Hazard Perception Checklist, in Unit 3.1 of Student Manual

Rules for Commentary Driving: Hazard Perception, in Unit 3.1 of Student Manual

Rules for Onstreet Driving, in Unit 1.1 of Student Manual

Driver's Duty Status Record (Driver's Daily Logbook) in which to record driving time/miles

Driver's License or Learner's Permit, as required in your State

Instructor Material

Hazard Perception Checklist (at end of lesson)

Clipboard and several extra copies of the Hazard Perception Checklist

Equipment

See Unit 1.8, Lesson 3 for details of vehicle requirements and also review the School Administrator's Manual

Ballast or dummy cargo sufficient to achieve at least a payload of fifteen-thousand (15,000) pounds is required (a 50-60,000 pound payload is preferable)

Eye movement check mirror to be mounted on sun visor or panel above student driver's head to allow instructor and observers to monitor student driver's eye movements

Accelerometers to measure both longitudinal acceleration (when braking) and lateral acceleration (in curves and turns - while not mandatory this is highly desirable to enable objective ratings of student's performance)

Tachographs and fuel flow (fuel economy) meters are also not mandatory but are highly recommended to improve instructor's quality of feedback to students and to insure maximum objectivity of student performance ratings

Content

Activity or Topic	Approximate Time
1. HAZARD RECOGNITION EXERCISE	6 hours

HAZARD RECOGNITION EXERCISE (6 hours)

Purpose

The purpose of this exercise is to expose students to recognize common road and traffic hazards in order to give them an opportunity to assess and broaden their hazard recognition capability.

Route

It is almost impossible to select routes specifically in terms of the great array of hazards characterized in highway traffic environment--particularly when the majority of them are dependent upon traffic and weather conditions that vary from one moment to the next. However, the following conditions, over all, should provide ample exposure to common hazards:

Road--A variety of road surface conditions and configurations, including:

- Narrow roads
- Degraded surfaces
- Deteriorating roadside conditions
- Overhead obstructions

Traffic--High density traffic conditions, including:

- Parked vehicles
- Pedestrian traffic in the road
- Merge points
- Congested areas
- Buses and taxis

Because of the number of onstreet lessons preceding this one, the student should be able to cope with the road and traffic conditions giving rise to common hazards.

Directions

In addition to the general procedures described in the Introduction, the following procedures should be used in this lesson

Duration--The intensity of effort involved in observing hazards, particularly during commentary driving, can be somewhat fatiguing. Therefore, it is wise to limit each behind-the-wheel stint to 15-20 minutes.

Commentary Driving--Five minutes out of each behind-the-wheel stint should be devoted to use of commentary driving techniques. These procedures will have been introduced in the preceding lesson, but should be reviewed with students prior to starting the lesson.

Identification of Hazards--The instructor should not call students' attention to hazards during driving since it will tend to distract their attention from identification of other hazards. The obvious exception is when a threat to safety exists.

Recording Performance--In contrast with previous street lessons, instructor and observers should record correct responses as well as those that are incorrect. Identification of correct responses will benefit student observers who may not have noticed the hazard or the student's response.

Method of Observation--The driver's recognition of a hazard must be inferred from one of the following observable responses:

Commentary--During the commentary driving phase, the driver's recognition of a hazard will be inferred from the driver's oral commentary.

Control Response--During driving without commentary, instructor and observers can infer hazard recognition by one or more of the following:

Changing Speed--Removing the foot from the accelerator, covering the brake, or applying the brake.

Changing Direction--Changing lanes or position within lane away from the hazard.

Signaling--Tapping the horn or flashing lights.

Observations

Any potential threat to the safety of the vehicle qualifies as a hazard. The number of hazards is far too large to be identified in this lesson plan or on the instructor's checklist. The instructor is referred to the classroom lesson plan for examples of common hazards. The categories listed below are provided on the student checklist in order to aid students both in identifying hazards and in reminding them of the specific hazards observed earlier during the critique sessions.

Road Characteristics--Characteristics of the road that provide hazard clues, including:

Surface--The appearance of the road surface providing clues to the following hazards:

Slippery Surfaces--Surfaces that could induce a skid.

Soft Surfaces--Surfaces that may not support the weight of the truck.

Sloping Surfaces--Surfaces that slope across the truck's path including the danger of skidding, rollover, or collision between the trailer and the roadside objects (high colonnades, sloping edges, unbanked curves).

Configuration--Clues to potentially dangerous roadway configuration including sharp curves, dangerous offramps, leave exits.

Road User Characteristics-Characteristics of road users that identify them as potential hazards, including:

Obstructed Vision--Clues indicating the inability of a road user to see the truck.

Distraction--Clues indicating that another road user may be distracted and, therefore, unable to devote attention to the truck.

Confusion--Clues that another road user may be confused and, therefore, a candidate for some unexpected action.

Low Speed--Clues indicating that a vehicle ahead is traveling at a speed that would cause the truck to overtake very quickly.

Incapacity--Clues that another driver is unable to respond appropriately to the truck because of intoxication, fatigue, or some other incapacity.

Road User Activities--Activity on the part of any road user that indicates a potentially hazardous course of action, including:

Driver Movement--Any motion on the part of the driver that signals an impending change in speed or direction.

Vehicle Movement--Any motion on the part of the vehicle that signals an impending change in speed or direction.

Pedestrian/Cyclists--Any motion on the part of a pedestrian, bicyclist, or moped rider that signals an impending change in speed or direction.

Conflict--Any vehicle that is on a collision course with an object or other road user, signaling an impending change in speed or direction, including conflicts with:

Obstructions--Roadway configurations with fixed objects in the path of the other vehicle.

Merges--Vehicles merging into the path of the other vehicle.

Intersections--Vehicles intersecting with the road user.

NOTE: An excellent procedure is to videotape the traffic scene for later classroom review and analysis with each student to help them better comprehend the selective eye seeing habits as exemplified in the "Smith-System" of driving.

UNIT 3.1

HAZARD PERCEPTION CHECKLIST

During Commentary Driving, check "Yes" if the driver correctly identifies and describes a driving hazard. Check "No" if the driver does not correctly identify and describe a hazard.

During Onstreet Driving Without Commentary Driving, use the checklist to indicate whether or not the driver responds correctly to a hazard.

HAZARD RECOGNITION	Driver #1		Driver #2		Driver #3	
DRIVER'S RESPONSE	YES	NO	YES	NO	YES	NO
Road Characteristics						
Surface						
Configuration						
Road User Characteristics						
Obstructed Vision						
Distraction						
Confusion						
Low Speed						
Incapacity						
Road User Activities						
Driver Movement						
Vehicle Movement						
Pedestrians/Cyclists						
Conflicts						
Obstructions						
Merging						
Intersecting						

Explanation of errors on back.

Explanation of Categories of Hazards on Unit 3.1 Checklist

Road Characteristics--Characteristics of the road that provide hazard clues, including:

Surface--The appearance of the road surface providing clues to the following hazards:
Slippery Surfaces--Surfaces that could induce a skid.
Soft Surfaces--Surfaces that may not support the weight of the truck.
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Conflict--Any vehicle that is on a collision course with an object or other road user, signaling an impending change in speed or direction, including conflicts with:

Obstructions--Roadway configurations with fixed objects in the path of the other vehicle.
Merges--Vehicles merging into the path of the other vehicle.
Intersections--Vehicles intersecting with the road user.

Notes:

Notes:

UNIT 3.2
EMERGENCY MANEUVERS

UNIT 3.2 EMERGENCY MANEUVERS

PURPOSE

The purpose of this unit is to enable students to carry out appropriate responses when faced with emergencies.

OBJECTIVES

Performance Objectives

The student must be able to

- bring the truck to a stop in the shortest possible distance while maintaining directional control on a dry surface.
- perform a quick evasive turn on a dry surface.
- make an evasive turn off of the roadway and back onto it while maintaining directional control.
- bring the vehicle to a stop in the event of a brake failure.
- maintain control of the vehicle in the event of a blowout.

Knowledge Objectives

The student must know

- that the vehicle can be turned more quickly than it can be stopped.
- that in an impending head-on collision, it is generally safer to leave the roadway than to strike another vehicle.
- procedures for quick stops, quick turns, and evasive turns off the roadway.
- procedures for handling brake failure and blowouts.

Skill Objectives

The student must be able to

- use brakes in a manner that will stop the vehicle in the shortest possible distance while maintaining directional control.
- turn the steering wheel 180° in either direction quickly while maintaining a grip on the steering wheel.

Attitude Objectives

The student must believe that

- a driver should never give up in efforts to cope with an emergency.
- it is safer to leave the road than to risk a head-on collision with another road user.

LESSONS

Lesson 1.	**Emergency Procedures (Classroom)**	**1 hour 30 minutes**
Lesson 2.	**Emergency Skills (Range)**	**4 hours**

LESSON 1 EMERGENCY PROCEDURES (CLASSROOM)

Overview

Time Allotted: 1 hour 30 minutes

Prerequisites: Unit 1.7, Lesson 2 - At least 35 hours completed

Purpose:

The purpose of this lesson is to discuss the importance of and methods for carrying out evasive steering, emergency stops, offroad recoveries, and responses to brake failures and blowouts. The lesson will end with a preview of the range maneuvers to be performed and safety precautions to be observed.

Materials

Instructional Aids

Visuals 1 - 15

Student Material

Emergency Maneuvers Checklist, in Unit 3.2 of Student Manual

Instructor Material

No additional material required

Content

Activity or Topic	Approximate Time
1. ROLE OF EMERGENCY MANEUVERS	12 minutes
2. EVASIVE STEERING	14 minutes
3. EMERGENCY BRAKING	8 minutes
4. OFF-ROAD RECOVERY	7 minutes
5. BRAKE FAILURE	12 minutes
6. BLOWOUTS	7 minutes
7. EMERGENCY MANEUVER PROBLEM SOLVING	20 minutes
8. RANGE PROCEDURES	10 minutes
	1 hour 30 minutes

1. ROLE OF EMERGENCY MANEUVERS (12 minutes)

Avoiding Emergency Maneuvers

The safest way to handle an emergency is to keep it from happening in the first place.

- The more often emergencies are encountered, the greater risk of accident
- With enough emergencies, sooner or later the driver will have an accident

Most emergencies arise through **DRIVER ERROR.**

- Emergencies arise when one or more drivers fail to employ safe operating practices
- Professional drivers reduce the likelihood of emergencies by employing all knowledges and skills taught in this course

Safe operating practices that will reduce likelihood of emergencies:

Vehicle Inspection (Unit 1.3)
- Will help to insure against vehicle failures likely to create an emergency practice (e.g., a brake failure)

Visual Search (Unit 2.1)
- Will help insure that drivers see emergency producing situations before they become real emergencies

Hazard Recognition (Unit 3.1)
- Will help insure that dangerous situations that drivers see are quickly and rapidly recognize as hazardous before they become emergencies

Communication (Unit 2.2)
- Will help insure that other road users know when a tractor-trailer is present and what it's driver plans to do and can thus avoid creating an emergency

Speed Management (Unit 2.3)
- Will help insure that when a potential emergency arises, the driver will have time to
    - Recognize and react to the situation
    - Maneuver the vehicle out of danger before a real emergency arises

Space Management (Unit 2.4)
- Will insure a sufficient amount of space for the stopping and swerving maneuver needed to let the driver recover from the mistakes of other road users

Night Operations (Unit 2.5)
- Will help the driver adjust to nighttime conditions to lessen the chances of an emergency

Extreme Driving Conditions (Unit 2.6)

Will help drivers to adjust to the extreme driving conditions to lessen the chance that emergencies will occur

Personal Health and Safety (Unit 5.5)

Will help insure that drivers are physically and emotionally prepared to cope with highway traffic conditions in a way that will lessen the chance that an emergency will arise

Safe operation will not always prevent emergencies
    No one is perfect; mistakes are bound to create emergencies
    It is therefore critical that students know how to handle emergencies when they arise
        Classroom instruction will describe the procedures for handling emergencies
        Range sessions will allow students to put knowledge into practice and develop the necessary skills

Importance of Emergency Maneuvers

Indiana University study showed that 1/3 of motor vehicle accidents could have been avoided with appropriate maneuvers
    Most drivers hit the brake
    Car skidded out of control
    Escape route was available

Correct response to emergencies must be learned
    Panic braking is a result of habit
        Drivers get used to braking in tight situations
        Brake in an emergency without thinking
    Must learn proper responses
    Must practice until they replace habitual responses

Types of Emergency Maneuvers To Be Taught

Evasive steering--Steering out of an emergency situation
Emergency stopping--Stopping quickly while under control
Offroad recovery--Using the roadside as an escape path
Handling brake failure--Stopping the truck when the brakes fail
Blowout--Maintaining control when a front tire blows
Skid Recovery--Regaining control of the vehicle when it has started to skid
    Skid recovery is the most complex of the maneuvers to be taught
    Will be taught as a separate unit (Unit 3 3 Skid Control and Recovery)

2. EVASIVE STEERING (14 minutes)

Importance

Reduces Likelihood of an Accident

- Truck can generally be turned more quickly than it can be stopped
- If an escape path is available, evasive steering provides a better chance of avoiding a collision than attempting to stop

Reduces Severity of Accident

- Evasive steering produces side-swipe at worse
- Head-on or rear-end collision could be fatal due to truck override

Possible Escape Routes

- Lane change--if an adjacent lane is entered, a quick lane change provides the best escape route
- Shoulder--If an adjacent lane is not available, the shoulder of the road provides an available escape route

Evasive Steering Is Generally Safe

- Quick evasive maneuvers will not generally cause a roll-over:
  - Not as dangerous as entering a curve or turn too quickly
  - The small chance of a roll over is better than a certain collision
    - Safest conditions for evasive steering
  - A stable cargo load - with low center gravity
  - A firm footing (adjacent lane or paved shoulder)

Visual 1 Evasive Steering

EXAMPLE: At highway speeds, car in visual is too close for the truck to stop
Oncoming vehicle keeps car from completing turn
Road to right offers possible escape
Room enough to swerve behind car
Swerve back on the highway after passing the car

General Procedures

The following procedures where evasive steering applies to all situations. Procedures for specific situations will be described next.

Minimize the Amount of Turning Necessary

- Start evasive steering as early as possible
  - Start as soon as an emergency is recognized
  - The earlier the driver starts, the smaller the amount of turn that is necessary

- Turn only as much as needed
  - Aim to just clear the obstacle
  - The larger the turn, the greater the chance of a rollover or jackknife

Turn As Quickly As Possible

- Use the hand-over-hand steering technique
- Each turn of the wheel should be approximately 180° (illustrate for students)
- This is the reason for placing the hands in the 9 o'clock-3 o'clock position
  - This position allows wheel to turn 180° without letting go of wheel
  - Hands won't be in this position unless done in normal driving

Proper Braking

- Avoid braking while turning
  - Could cause tractor and trailer wheels to lock up
  - Locking wheels during turn could result in loss of control
- Brake before turning
  - If distance permits, apply the brakes hard before beginning the turn
  - Proper braking technique will be described later
- Braking as much as possible reduces the speed before turning
  - Allows vehicle to be turned more sharply
  - Reduces chance of rollover or jackknife in turn

Countersteer

- Must be prepared to countersteer quickly
  - "Countersteer" is term given to a turn back toward intended path of travel
  - Quick countersteer needed to keep from going out of escape path (e.g., off the shoulder)
- Initiate countersteer as soon as front of trailer clears obstacle
- Importance of safety belt
  - Difficult to turn steering wheel quickly unless firmly rooted on the seat
  - Quick turn may cause unbelted driver to slide out of seat
    - Can't steer unless in driver's seat
    - Many "secondary collisions" result from loss of control
      - Driver swerves to avoid obstacle
      - Can't turn back again
      - Crashes off road

Specific Procedures

How an evasive maneuver is performed depends upon the specific situation

Specific procedures needed for emergencies involving oncoming vehicles, stopped vehicle ahead, and merging vehicle

Oncoming Vehicle

- Driver conditions produce emergency
- Driver is obviously impaired (e.g., intoxicated)
- Driver can't control vehicle (e.g., swinging wide in a turn)
- Evade to the right
- Blast horn to gain driver's attention
- Oncoming driver will tend to turn to (his) right
- Do not steer to the left
  - Entering a left lane is illegal
  - Will simply cause collision to occur in the left lane
- Leaving the road is preferable to a headon collision

Stopped Vehicle Ahead

- Conditions producing emergency
  - Vehicle ahead stopped suddenly (when driver of truck has been following too closely)
  - Truck comes over the crest of the hill and finds a stalled vehicle in the middle of the road
- If next to a clear oncoming lane
  - If the left lane is clear
    - Turn left into the oncoming lane
    - Better than a swerve to the right since it eliminates the chance of sideswiping an adjacent vehicle
  - The height of the cab allows to see if the left lane is clear
  - This is one situation in which it is safe to turn into the left lane
- If next to a clear shoulder
  - Good shoulder should provide stable surface
  - Eliminates chance of sideswipe
- If in the middle lane of a multilane road
  - If one lane is obviously clear, use it
  - Otherwise, evade to the right; if there is a vehicle in the adjacent lane, it is better to force it to the shoulder than to force a vehicle into an oncoming lane

Converging Vehicle

- Conditions leading to an emergency
  - Another vehicle attempting to change lanes into the lane occupied by the truck
  - Another vehicle merging onto the highway and not yielding to the truck
  - Vehicle starting to pull out of from a side street, driveway, or parking space
  - Pedestrian or cyclist about to enter the roadway
- Blast horn
  - Generally "freezes" the other driver (i.e., makes the driver stop quickly)
  - Making the driver stop minimizes the amount of evasive steering necessary
  - Studies show that drivers are frequently reluctant to use horn in emergency

    - Use of the horn could prevent many accidents that occur
    - Causing annoyance to another driver is better than a collision
- Swerve away from merging vehicle
  - Don't try to steer behind the other vehicle
    - If the other vehicle stops, a right angle collision will result
    - Turning away from the merging vehicle will produce a sideswipe accident at worse
  - Exception: An oncoming vehicle
    - Don't steer away from merging vehicle if it puts the truck in the path of an oncoming vehicle
    - Better to collide with the merging vehicle at an angle than swerve into the path of an oncoming vehicle

3. EMERGENCY BRAKING (8 minutes)

Conditions Requiring Emergency Braking

- When there is room enough to stop
  - When there is room, a quick stop is safer than an evasive turn
    - Does not risk collision with unseen vehicle
    - Less likely to produce a rollover or jackknife
  - When evasive steering is not possible
    - Braking is the only alternative
    - Even where vehicle cannot be brought to a stop, impact may be reduced
    - Minimizes damage
    - Lessens chances of injury or fatality

Importance of Braking Technique

Over-Application of Brake

- Locks up vehicle's wheels
- Causes vehicle to skid (to be discussed in Unit 3.3)

Skid Can Produce Jackknife

- Damage to tractor-trailer
  - Trailer can collide with tractor in a jackknife
  - Either tractor or trailer may collide with trees, buildings, or other structures along the side of the road
- Collision with other vehicles
  - As trailer swings around it can collide with vehicles in other lanes
  - Loss of control during jackknife can cause entire rig to cross into other lanes

Proper Braking Technique

- Brings vehicle to a stop in minimum distance
- Allows control to be maintained during the stopping maneuver

Visual 2 Emergency Braking

EXAMPLE: Car in visual

- Tanker pulling into truck's path
  - Truck will overtake tanker quickly
  - Vehicles in left lane and on shoulder prevent evasive steering
- There is limited distance to stop before hitting the truck
  - Emergency braking technique is the safest maneuver
  - There is sufficient room to bring the truck to a stop
  - Correct braking will avoid skidding into other vehicles
  - Evasive steering is unnecessary

Procedure

Two emergency braking techniques can be used
- Controlled braking
- "Stab" braking

Both will prevent a skid or jackknife

Controlled Braking

- Technique
  - Apply brakes just short of "wheel lockup"
  - Maintain steady pressure on brakes
- Limitations of controlled braking
  - Difficult to anticipate point of lockup precisely
  - Point of lockup different for each vehicle
  - Developing skill in controlled braking technique requires practice in the specific vehicle to be operated
  - Without an opportunity to practice, "stab" braking is best

"Stab" Braking

- Apply brake fully
- Release brake partially when wheels lock
  - Achieves maximum braking while applied
  - Releasing avoids skid
- Reapply brake when wheels start to roll again
- Repeat "stab" braking sequence until vehicle slows sufficiently for safe stop or turn maneuver
- Between each "stab", allow time for the wheels to roll again
  - Reapplying too quickly can result in skid
  - It generally takes about 1/2 - 1 second for wheels to start to roll again

Remove Visual

4. OFF-ROAD RECOVERY (7 Minutes)

Importance

Roadside May Provide Best Escape Path

- Use of roadside is better than a collision with another vehicle

    On right shoulder of the road
    On median strip, where a shoulder is provided

Most Drivers Fearful of Leaving Roadway

- Habit--Staying on the roadway is a strongly ingrained habit
- Fear--Afraid that the shoulder won't support the tractor-trailer

Myths: Drivers often hear of crashes resulting from use of the roadside for an evasive maneuver

- Most roadside crashed resulted from a driver error
    - Driver was distracted or fell asleep
    - Invented a "phantom" vehicle to explain leaving roadway
  - Successful evasive maneuvers do not result in accident and are therefore generally not reported

Resistance To Leaving the Roadway Causes the Drivers to Wait Too Long

- Don't wait until there is no chance to turn
- Successful offroad recovery often requires leaving the roadway immediately
- Most accidents making use of offroad recovery are due to incorrect technique

Offroad Recovery Generally Safe When the Roadside Is

- Wide enough to accommodate vehicle, e.g., no ditch or culvert
- Firm enough to support vehicle
  - Soft mud dangerous
  - Gravel and sand are generally safe

Visual 3 Offroad Recovery

Procedure

Brake Before Turning

- Reduce speed as much as possible
- Use controlled or stab braking to prevent loss of control

Avoid Braking While Turning

- Vehicle vulnerable to skid while turning
  - Trailer wheels or tractor wheels tend to skid sideways in a turn
  - Tendency to skid accentuated if brakes are locked
  - Discussed further in Unit 3.3, Skid Recovery
- Steering control is particularly important while entering roadside
  - Gravel or dirt on roadside reduces traction
  - Reduced traction increases possibility of skidding

Minimize Turning

- Keep one set of wheels on pavement if possible
  - Traction is better on pavement
  - Helps to maintain control of steering

- Reduce amount of turning on roadside
  - Maintain as straight a course as possible
  - Each turn creates the danger of skid

If Roadside is Clear

- Suppress tendency to return to the roadway
- Grasp wheel firmly and concentrate on steering
- Stay on roadside until vehicle comes to a complete stop
- Allow engine compression to stop vehicle
- Apply brakes only after speed is reduced
- Signal and check mirror before returning to travel lane

If Roadside Blocked

- May be blocked by parked vehicle, telephone pole, sign, bridge abutment, etc.
- Allow vehicle to slow as much as possible before returning to road
- Turn wheel sharply toward roadway
  - Describe the hazard of gradual return
    - Tires can't surmount pavement edge
    - Scrub along roadside
    - Suddenly climb pavement edge without warning
    - May enter far lane before driver gains control
  - Turning sharply allows driver to determine point of return
    - Won't be caught by surprise
    - Can be ready for countersteer

Countersteer

- Upon returning to the roadway, turn quickly in the direction of the roadway
- Turn as soon as right front wheel rides up on surface
- Both turning back on the roadway and countersteering should be executed as a single, integrated steering maneuver

Wheels Drop Off Pavement

- Often occurs if truck is driving close to edge
- Avoid immediate return to roadway
  - Control can be easily maintained with two wheels on pavement
  - Quick return has caused many vehicles to overturn or else veer across roadway--you must come to a complete stop before attempting to steer back onto pavement
- Follow same procedure as offroad recovery
  - If road is clear, let vehicle slow to a complete halt before returning to roadway
  - If roadside is blocked, return to road in the same manner as described above

5. BRAKE FAILURES (12 minutes)

Problem of Brake Failures

- Well-maintained brake system rarely fails completely
- Several fail-safe devices are designed to prevent brake failures from causing an accident

Despite this, brake failures may occur, resulting in runaway vehicle
If driver keeps cool, vehicle can generally be brought under control

Causes of Brake Failure

Loss of Air Pressure

- Leak in air system
- Warning buzzer sounds when air is low
  - Driver should stop immediately
  - Further loss could prevent stop
- Brakes will apply when air loss reaches critical level
  - System retains enough air to stop vehicle
  - Brakes are applied automatically
  - If loss is too fast, air could be exhausted before vehicle is stopped
- Independent trailer brake valve won't activate trailer brakes because they depend upon air system also
- On vehicle equipped with spring loaded parking brakes
  - Brakes will activate automatically when air pressure fails
  - Will generally bring the trailer to a stop if it is not on a steep downgrade

Air Blockage

- Air prevented from reaching brakes
- Common cause: water in air system freezes

Brake Fade

- On long downgrades, brakes may overheat
- Lose power to stop wheel rotation
- Won't cool off quickly enough

Mechanical Failure

- Can result from failure in mechanical linkage
- Rarely affects all brakes at once
- Vehicle can generally be stopped

Procedure

Downshift

- First thing to attempt when the vehicle is on a level surface
  - Increases engine braking
  - In case of air loss, raises rpm to increase air pressure
  - Do not attempt to downshift on a downgrade (review reasons as described in Unit 2.6, Extreme Driving Conditions)
  - Repeat downshifting until vehicle is moving slowly enough to stop with spring loaded parking brake

Find Escape Path

- Begin looking for escape path immediately
- Use the best path available

    - Don't wait to see if vehicle can be stopped after all
    - There may be no good escape paths available
- Possible escape paths
    - Side roads, particularly a road turning uphill
    - Open field
        - Possible damage to under carriage is better than collision
        - Try to turn uphill to stop the vehicle
    - Runaway vehicle escape ramps
- Create drag
    - Find some way of creating drag against vehicle motion
        - City: scrub tires against curb
        - Country: drive into heavy brush, small bushes

Inspect Brakes

- If possible, pull off the road just before the vehicle comes to a stop
- Inspect to find cause
- Don't return to the road until problem is corrected
    - Don't try to "nurse" vehicle to a repair facility
    - Some drivers have survived brake failure only to crash later
    - Call dispatcher or repair facility for a tow

6. BLOWOUTS (7 minutes)

- The term "blowout" refers to a sudden loss of tire inflation
- Can result from a variety of causes
    - Tire worn thin
    - Crack in tire casing
    - Damage from debris, potholes, nails
- Blowouts resulting from wear can be prevented by good pretrip inspection

Blowout Consequences

- Front tire
    - Disrupts steering
    - Can cause vehicle to veer
- Rear tractor tire
    - May feel rear of tractor slide from side to side
    - May give no symptoms at all
- Trailer tire
    - Rarely gives any symptoms
    - May not be noticed except through mirrors

Front Tire Blowout Procedure

Recognize Symptoms

- Loud bang
    - Like gunfire or backfire
    - Often sounds like it comes from another vehicle
    - Tire can deflate suddenly without sound
- Vehicle handling (review "Consequences" above)

Grasp Wheel Tightly

- Must respond immediately to sound or front end drop
- Wheel can be pulled from grasp before driver knows what's happened
- Important reason for maintaing proper grip on steering wheel at all times
  - Hands in the 9 o'clock - 3 o'clock position
    - Allows driver to resist the turn of the wheel better
    - Steering wheel less likely to be pulled from driver's grasp
  - Thumbs pointed upwards on outside of rim
    - Dangerous to have thumbs around rim or under wheel spoke
    - Force on steering wheel from blowout could break driver's thumb

Avoid Braking

- Braking produces forward weight shift
- Places more weight on front end
- Wheel more likely to lock up if tire has blown
- Makes control even harder to achieve
- Allow vehicle to slow gradually

Stop Vehicle

- When vehicle has slowed down, apply brake gently
- Pull offroad when vehicle is going very slowly
- Brake gently to a stop

Rear Tire Blowout Procedure

Not generally as dangerous as a front tire blowout

- Does not pull on the steering wheel
- Trailer may heel to the side of blown tire
  - Avoid braking
  - Wait until vehicle has slowed and then apply brakes gently
  - Pull offroad when vehicle is going very slowly
  - Brake gently to a stop
- Should stop and change tire as soon as possible. Hazards:
  - Tire shreds can damage air lines, or other parts
  - Can catch fire
  - Rim damage if tire comes off
  - Illegal to operate
  - Damage to other vehicles

7. EMERGENCY MANEUVER PROBLEM SOLVING (20 minutes)

The instructor will present the remaining visuals and discuss each in turn

- Present visual
- Describe conditions
- Have students present solution
- Critique solutions

Review correct procedure
Discuss how problem might have been avoided through safe operating practices
    Search, Communication, Speed and Space Management

Visual 4 Oncoming Car Passing

Problem 1: OnComing Car Passing

Situation

55 mph
Oncoming car attempting to pass two cars
Lead car is a compact (wasn't seen)
Committed to pass
High curbing on right

Solution

Brake, to reduce speed as much as possible
Squeeze as far to the right as possible
Oncoming cars will also squeeze to the side; should allow an alley for the passing car
Avoid attempting to surmount curb
    Could bounce vehicle back into the center of road
    Trees on right create additional hazard

Visual 5 Pedestrian in Street

Problem 2: Pedestrian in Street

Situation

35 mph
Four-lane divided highway
Pedestrian runs into street 75 feet in front of rig
Low curb at right

Solution

Not enough time to brake
Pedestrian may continue, stop, turn around
Best escape is roadside to the right; curb easily surmounted, plenty of open space
Don't sound horn; might encourage pedestrian to turn back

Visual 6 Left Turning Car

Problem 3: Left Turning Car

Situation

40 mph
Car parked on right cuts across to make left turn

Solution

Veer to the right just far enough to pass behind the car
No vehicles parked on right
Not enough time to brake; attempt could cause skidding
Don't use horn; could encourage other driver to stop rather than continue

Visual 7 Bicyclist

Problem 4: Bicyclist

Situation:

30 mph
Bicyclist 75 feet ahead
Bicyclist swerves in front of rig

Solution

Brake to reduce speed
Honk horn; cyclists will tend to swerve back to the right
Swerve left. No cars coming; maximize distance from cyclist

Visual 8 Car Pulling Out

Problem 5: Car Pulling Out

Situation

Two-lane city street
Parallel parking
Car pulls out about one car length ahead

Solution

- Swerve left
    - No oncoming cars
    - No cars could be (legally) overtaking on the left

- Don't brake
    - Not enough time
    - Could cause skid
- Honk horn
    - Should cause driver of the car to stop
    - Minimizes the degree of swerving necessary to avoid the car

Visual 9 Head-on Collision

Problem 6: Head-on Collision

Situation

55 mph
Two-lane road

Solution

Blast horn and flash headlights to encourage return to lane
Flash headlights
Swerve right
Try to keep wheels on pavement
Concentrate on steering
Allow vehicle to come to a complete stop before pulling back on highway; no obstructions on shoulder

Visual 10 Fallen Motor Cyclist

Problem 7: Fallen Cyclist

Situation

45 mph
Being passed by oncoming car and car on the right
Grassy shoulder on the right
Motorcycle rider ahead falls down

Solution

- Brake hard
- Ease off somewhat and start swerving right
  - Forces passing car to the right
  - Sideswiping passing car is better than hitting motorcyclist or oncoming car
- Don't bother with horn; it won't do any good

Visual 11 Ice-Cream Truck

Problem 8: Ice-Cream Truck

Situation

25 mph
Ice-cream truck traveling 100 feet ahead
Ice-cream truck stops as child runs out

Solution

Brake to a stop (controlled or stab)
Plenty of room to stop
Parked car and oncoming car prevent evasive steering

Visual 12 Hill Crest

Problem 9: Hill Crest

Situation

Two-lane highway
50 mph
Coming over hill
Oncoming car 150 feet ahead

Solution

- Brake hard to reduce speed
- If oncoming car cannot get back into lane, swerve to the right enough to miss the car
- If necessary, drive off into the grass and light trees on the right
  - Will cause only minor damage
  - Better than head on collision
- Not enough room to brake to a stop

8. RANGE PROCEDURES (10 minutes)

Brief preview of range procedures

NOTE: Instructor should review the range procedures in Lesson 2 Emergency Skills before conducting this classroom preview.

Visual 13 Emergency Stop

Emergency Stop

Students will
- Approach maneuver area at speeds increasing from 10 to 30 mph
- Upon reaching the Braking Point, apply brakes
- Using "stab" braking technique, bring the vehicle to a straight line stop

Visual 14 Evasive Steering

Evasive Steering

Students will
- Approach maneuver area at speeds ranging between 20 and 25 mph
- At "decision point" when the instructor indicates which path to take:
  - Steer along the path indicated by the instructor
  - Avoid braking

Repeat the preceding exercise, "stab" braking to a stop at the stop line
- Repeat the preceding exercise, applying the brakes once before turn

Visual 15 Offroad Recovery

Offroad Recovery

Students will
- Approach the offroad recovery area at speeds increasing from 10 to 30 mph
- Upon reaching the first pair of cones, turn so that the right wheels drop into the offroad recovery area
- Upon passing the last cone on the left - slow down to near halt or full halt depending on the instructor's command
  - Turn back onto the paved surface
  - Countersteer and exit along the path indicated
- Repeat the preceding exercise dropping all right side wheels into the offroad recovery area

NOTE: In actual driving situation, the failure to come to a complete stop can be extremely dangerous.

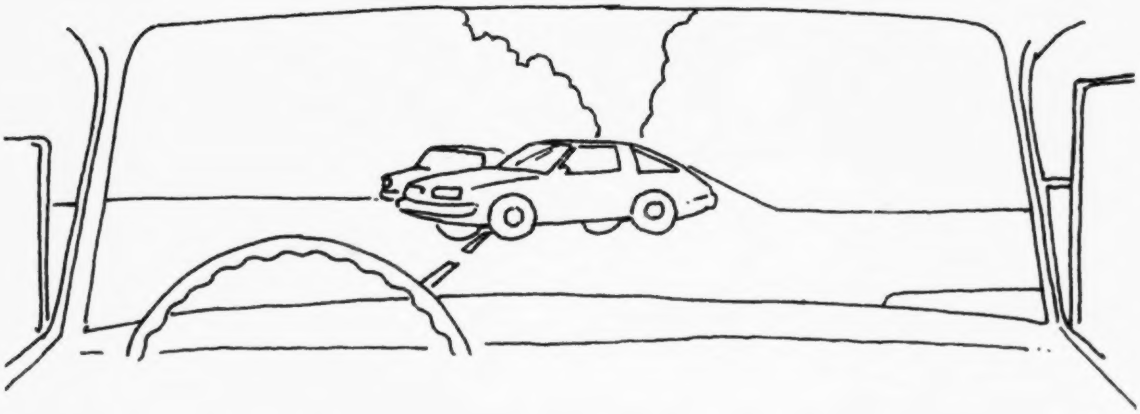
Safety Procedures

Follow the range safety rules provided in Unit 1.1 with the following additions:

- Only the driver and the instructor will be in the vehicle during emergency maneuver exercises
    - Violence of maneuvers cause observers to bounce around inside cab
    - Observers can see what's happening better from the outside
- When student is driving, follow instructor's directions to the letter
    - Do not move the vehicle until directed to do so
    - Drive only where directed
    - Observers will remain completely outside the maneuver area when not driving

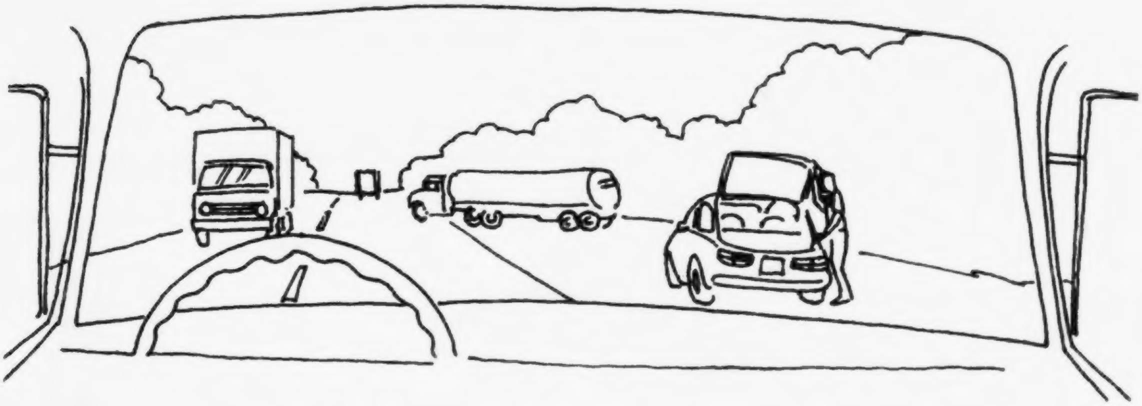
Visual 1

Evasive Steering



- Minimize Turn
- Turn Quickly
- Avoid Braking
- Countersteer

Emergency Braking

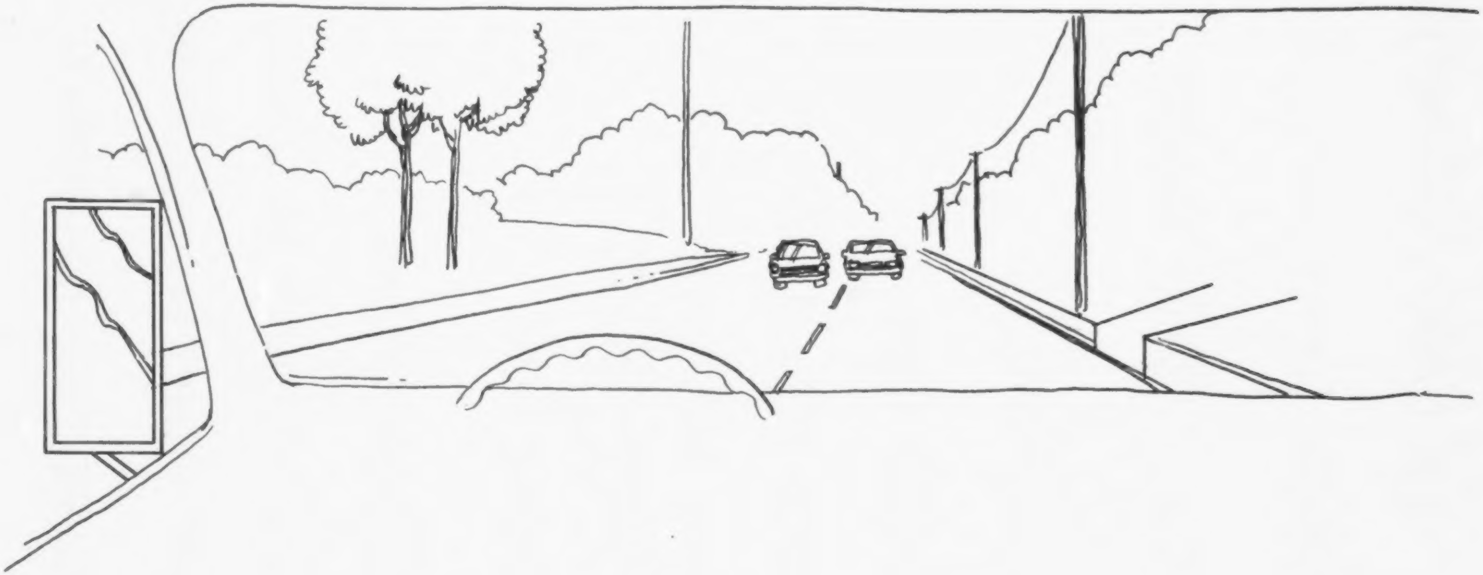


- Controlled Braking
  - Apply Brakes Just Short of Wheel Lockup
  - Maintain a Steady Pressure on Brakes
- Stab Braking
  - Apply Brakes Fully
  - Then Release Brakes Fully
  - Continue to Alternate Rapidly Between Fully Applied and Released

Off-Road Recovery

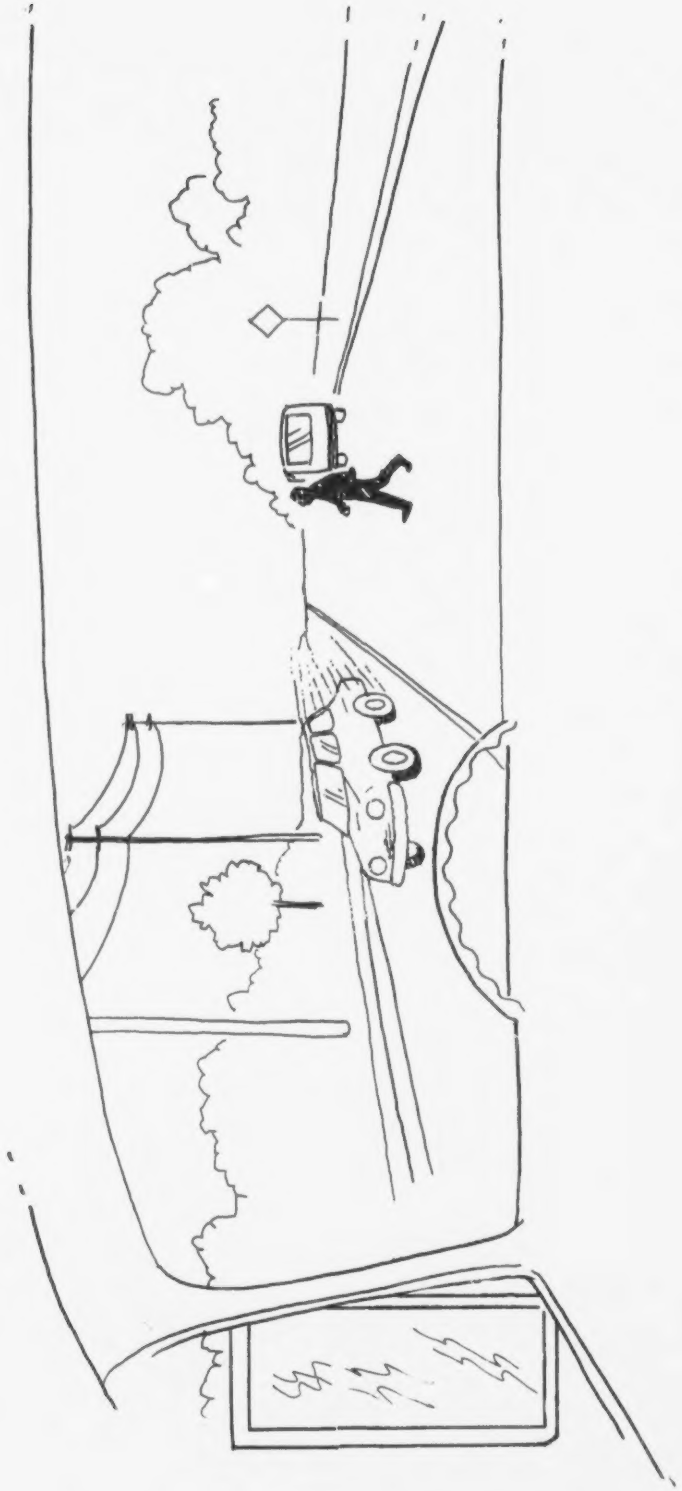
- Brake Before Turning
- Avoid Braking While Turning
- Minimize Turning
- If Road Side Clear
  - Concentrate on Steering
  - Allow Vehicle to Come to a Complete Stop
  - Reenter Road
- If Road Side Blocked
  - Slow as Much as Possible
  - Turn Wheel Sharply Toward Roadway
  - Countersteer Immediately

On-Coming Car Passing



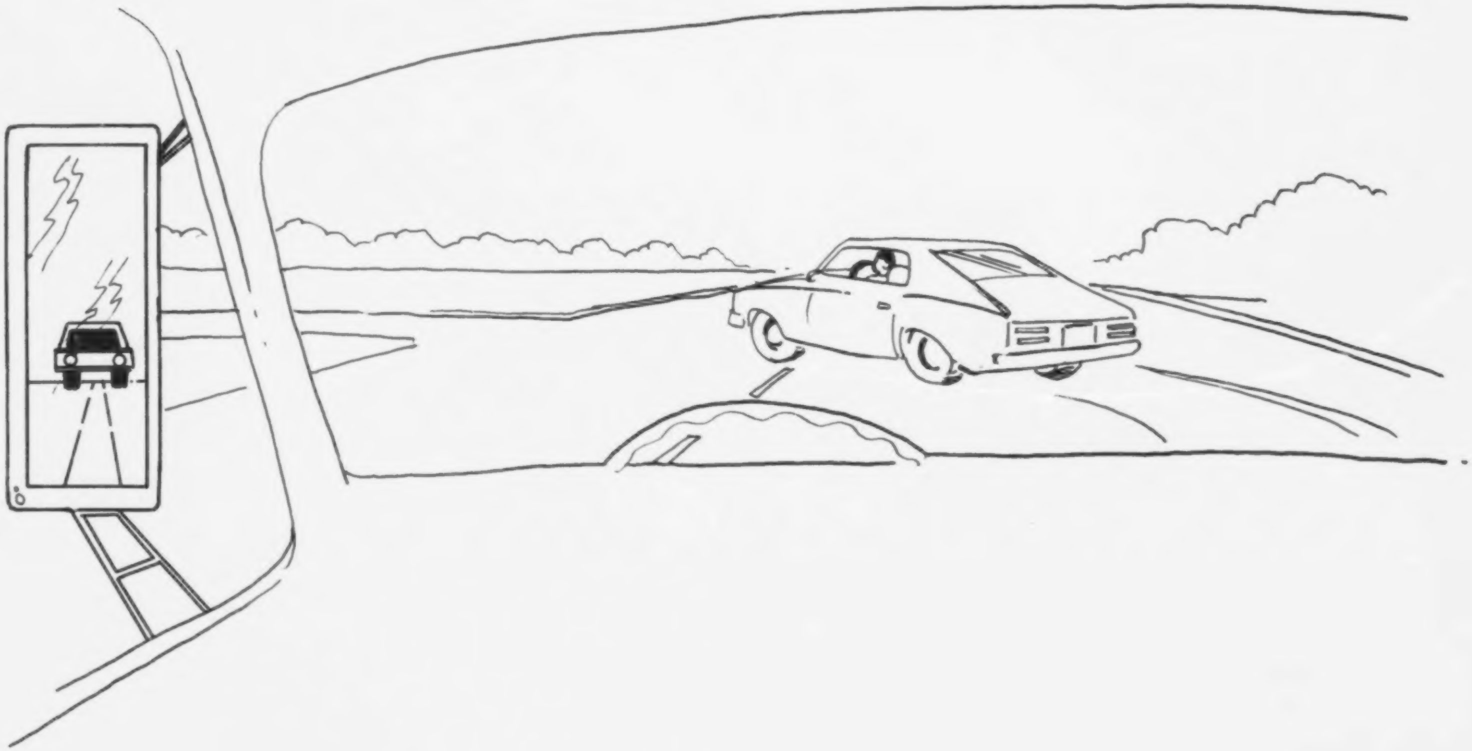
Visual 5

Pedestrian in Street



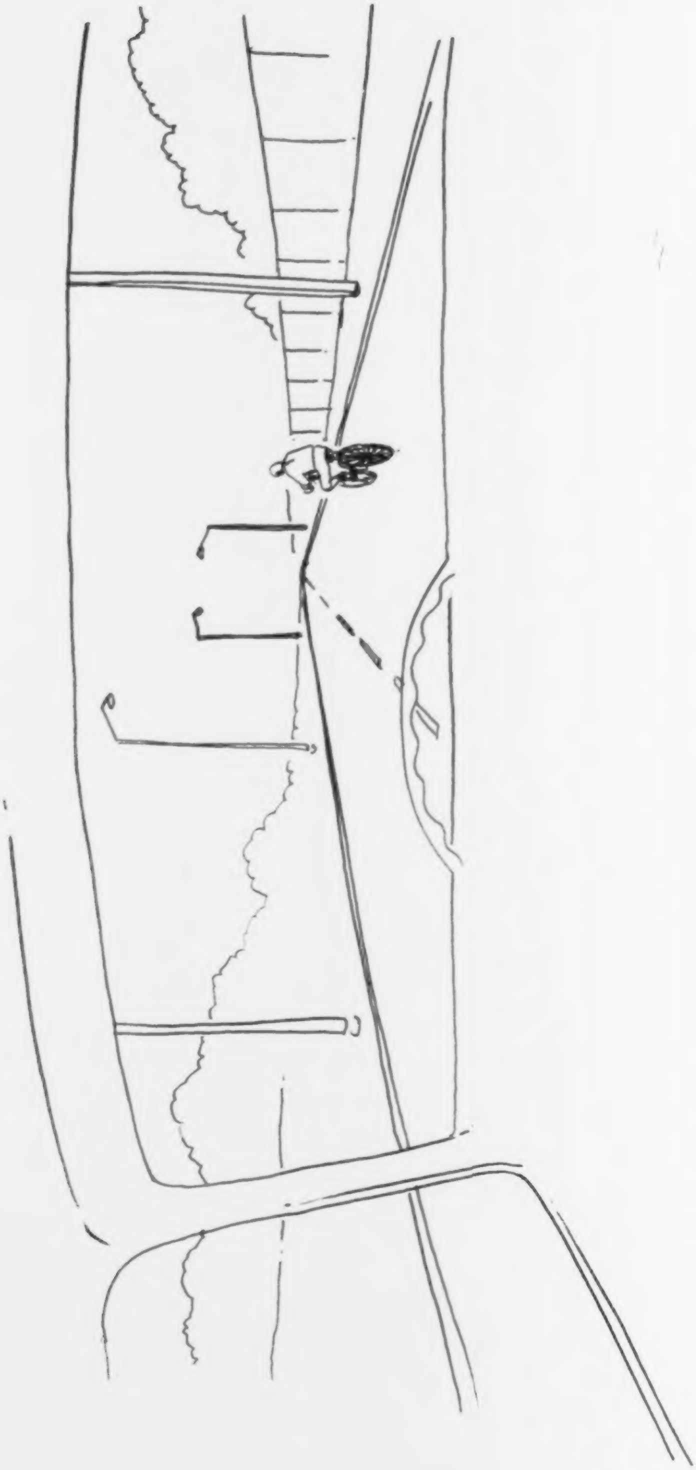
Visual 6

Left Turning Car



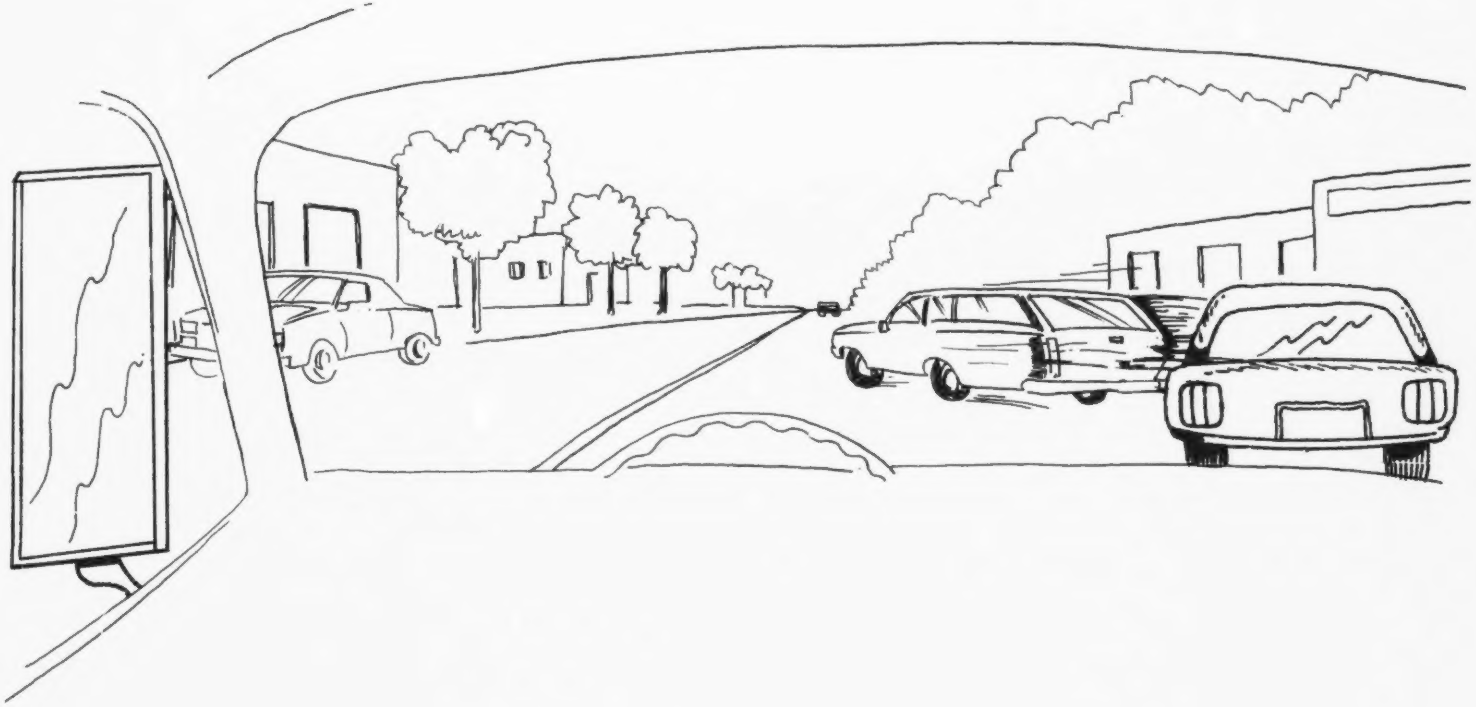
Visual 7

Bicyclist

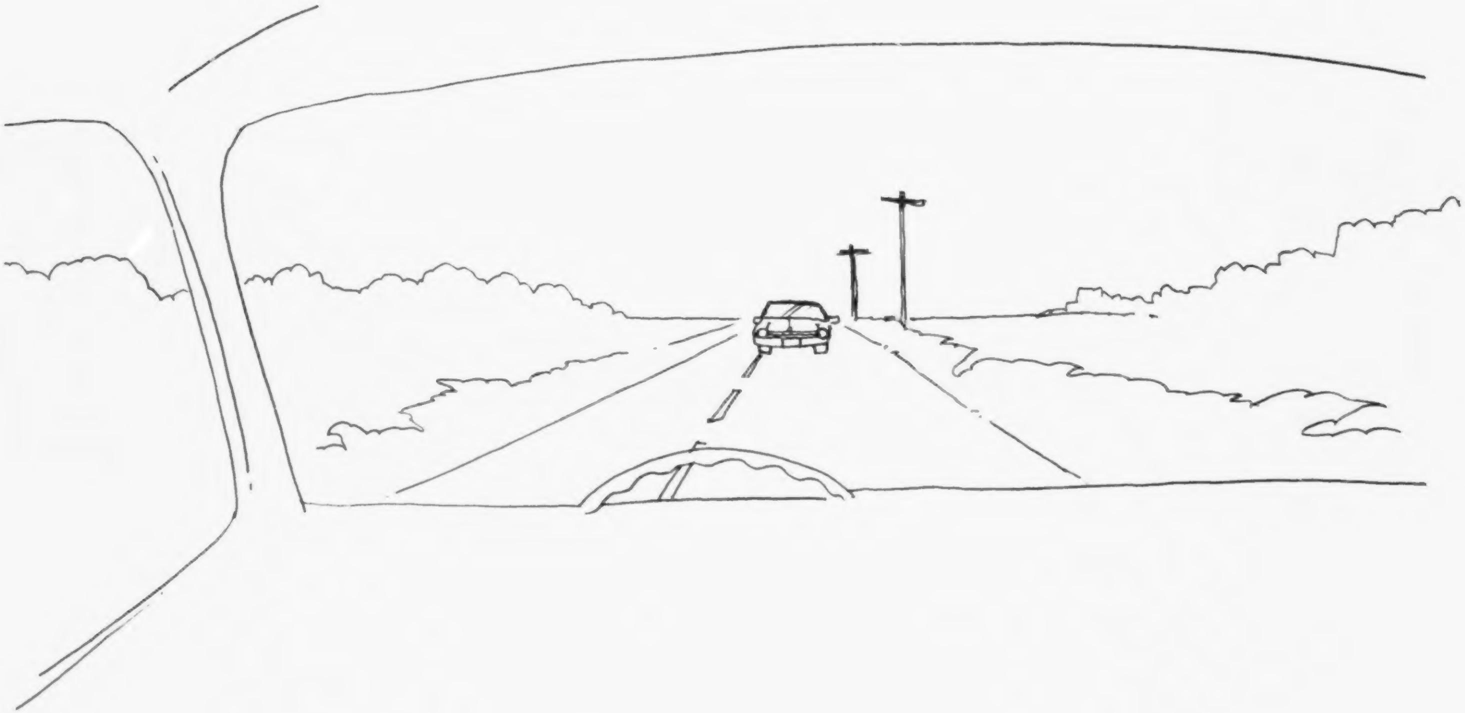


Visual 8

Car Pulling Out

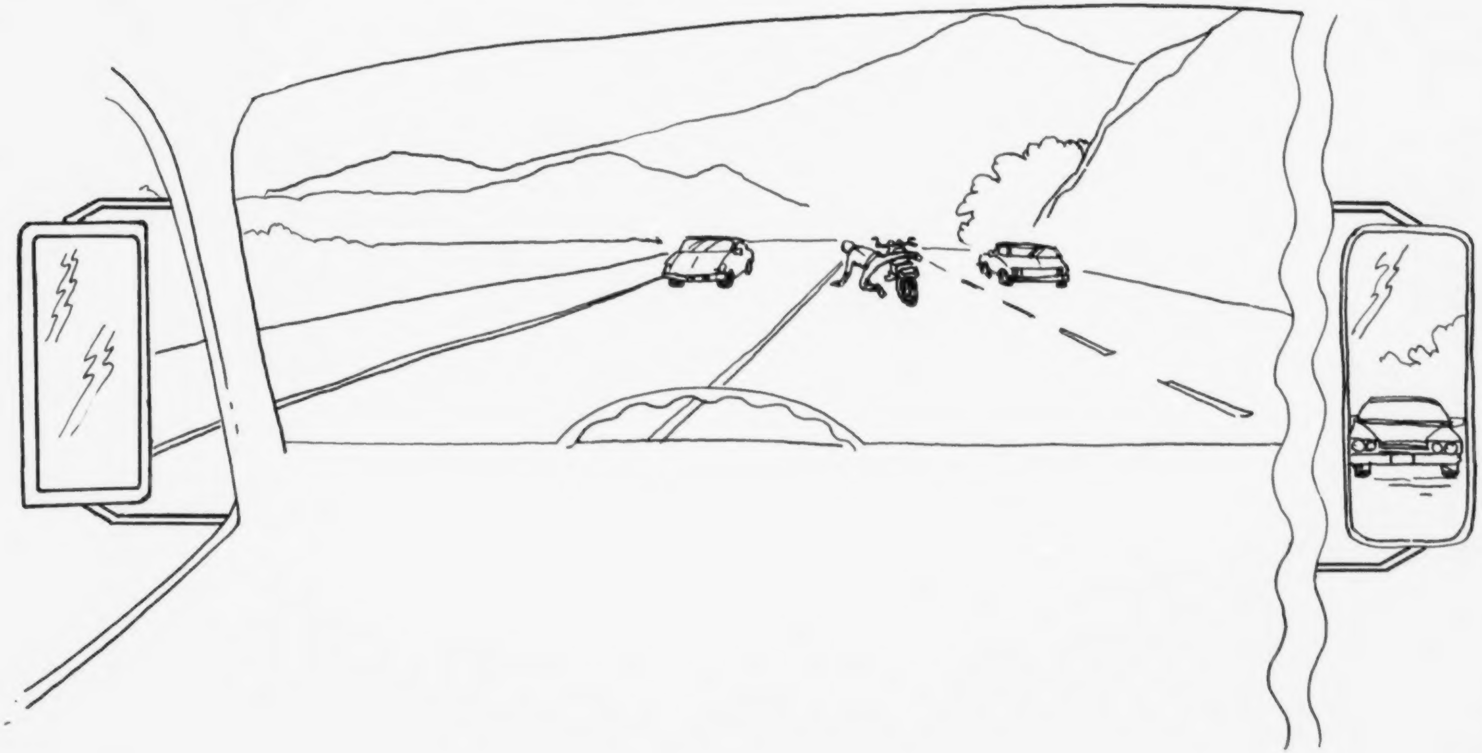


Head-on Collision



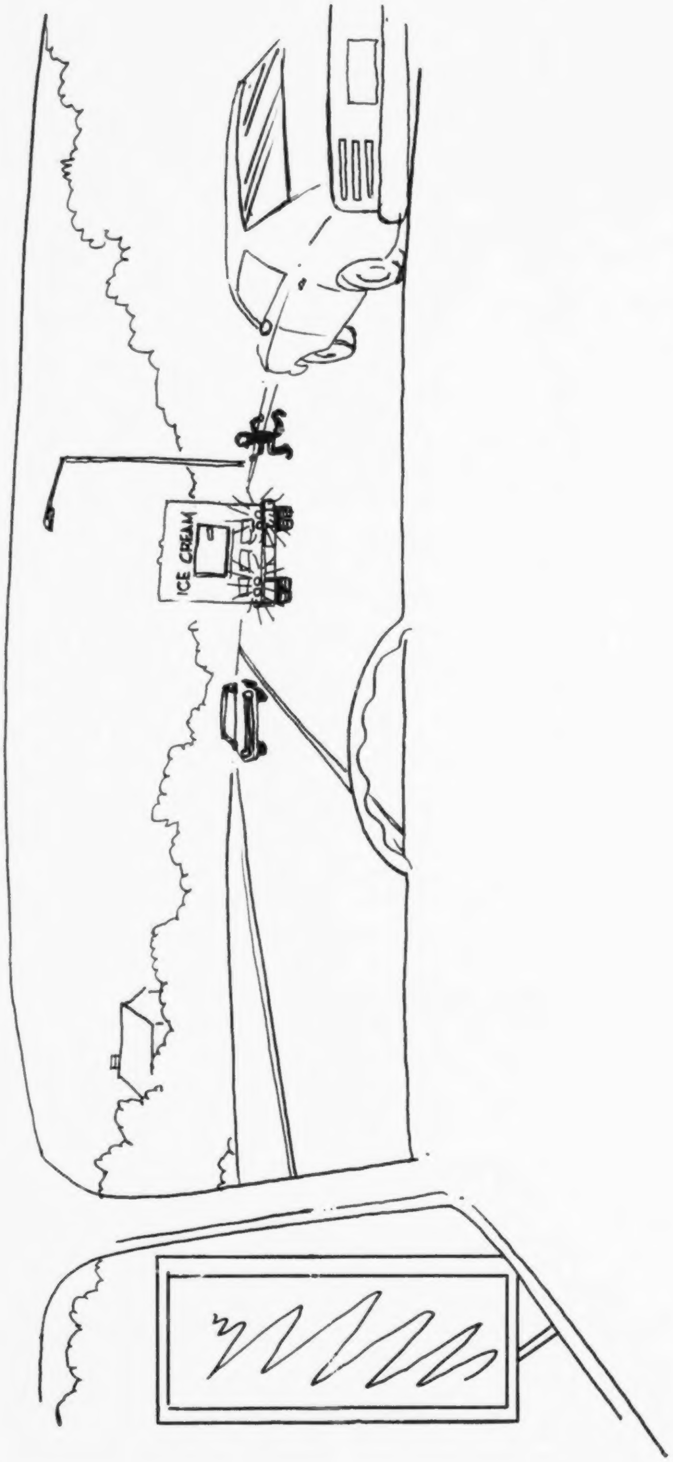
Visual 10

Fallen Motorcyclist

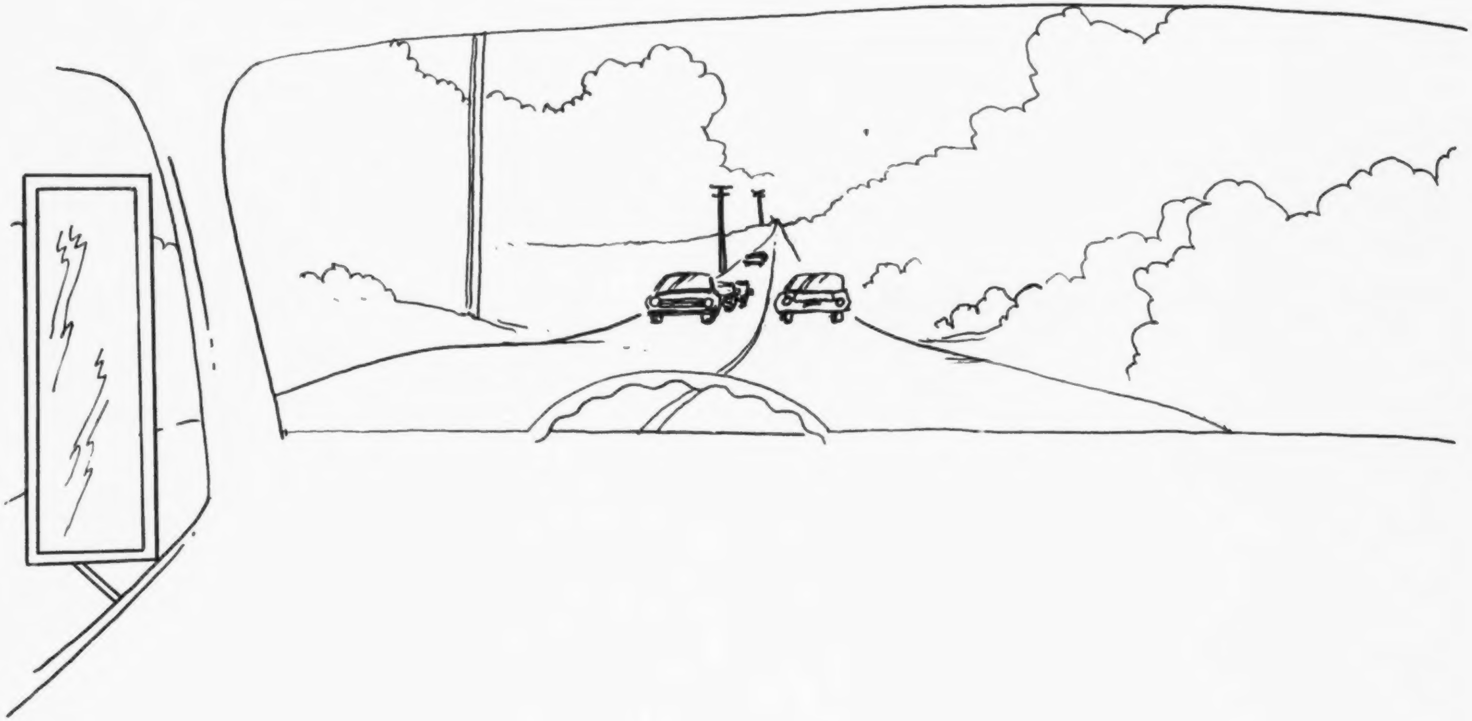


Visual 11

Ice Cream Truck

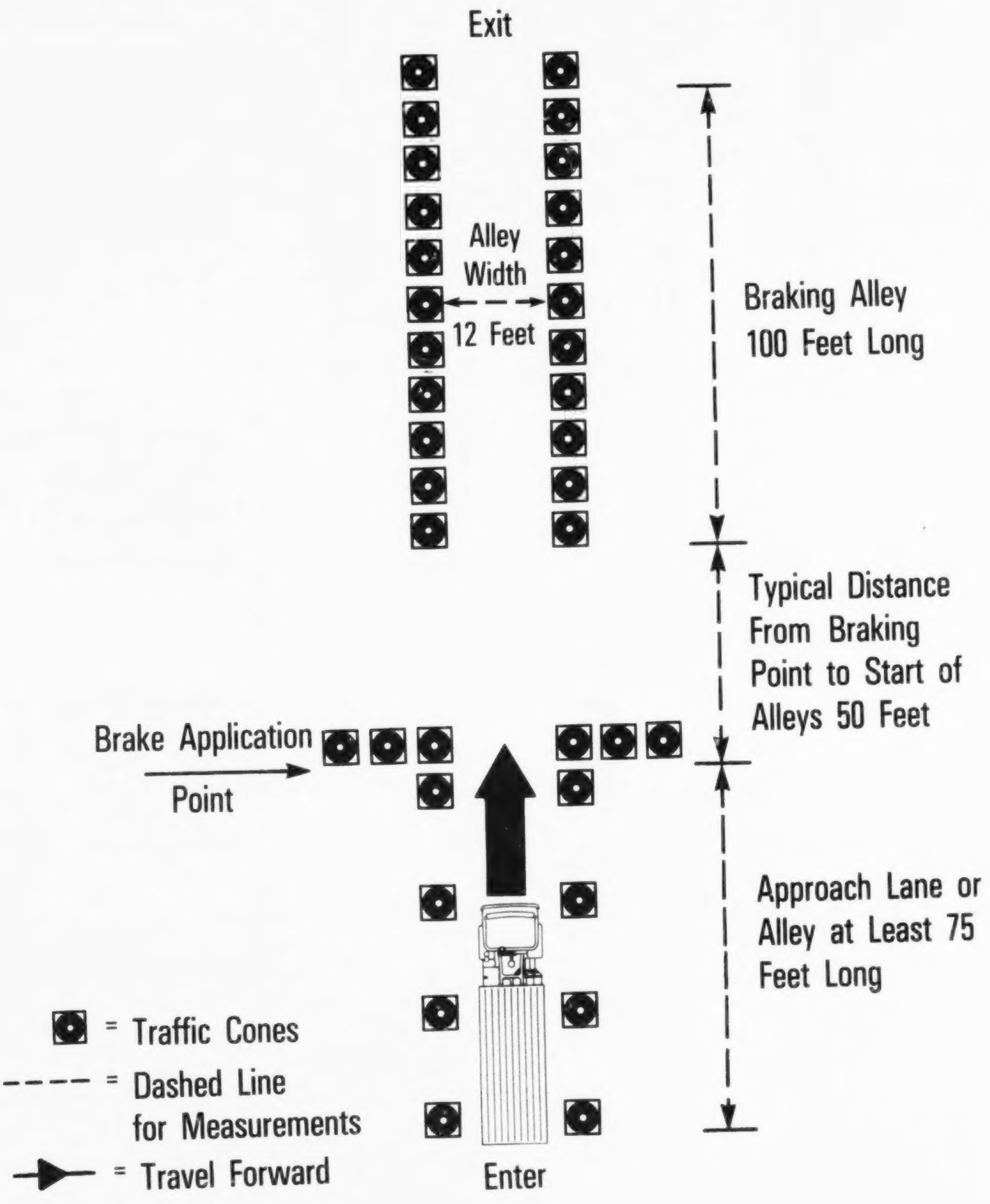


Hill Crest



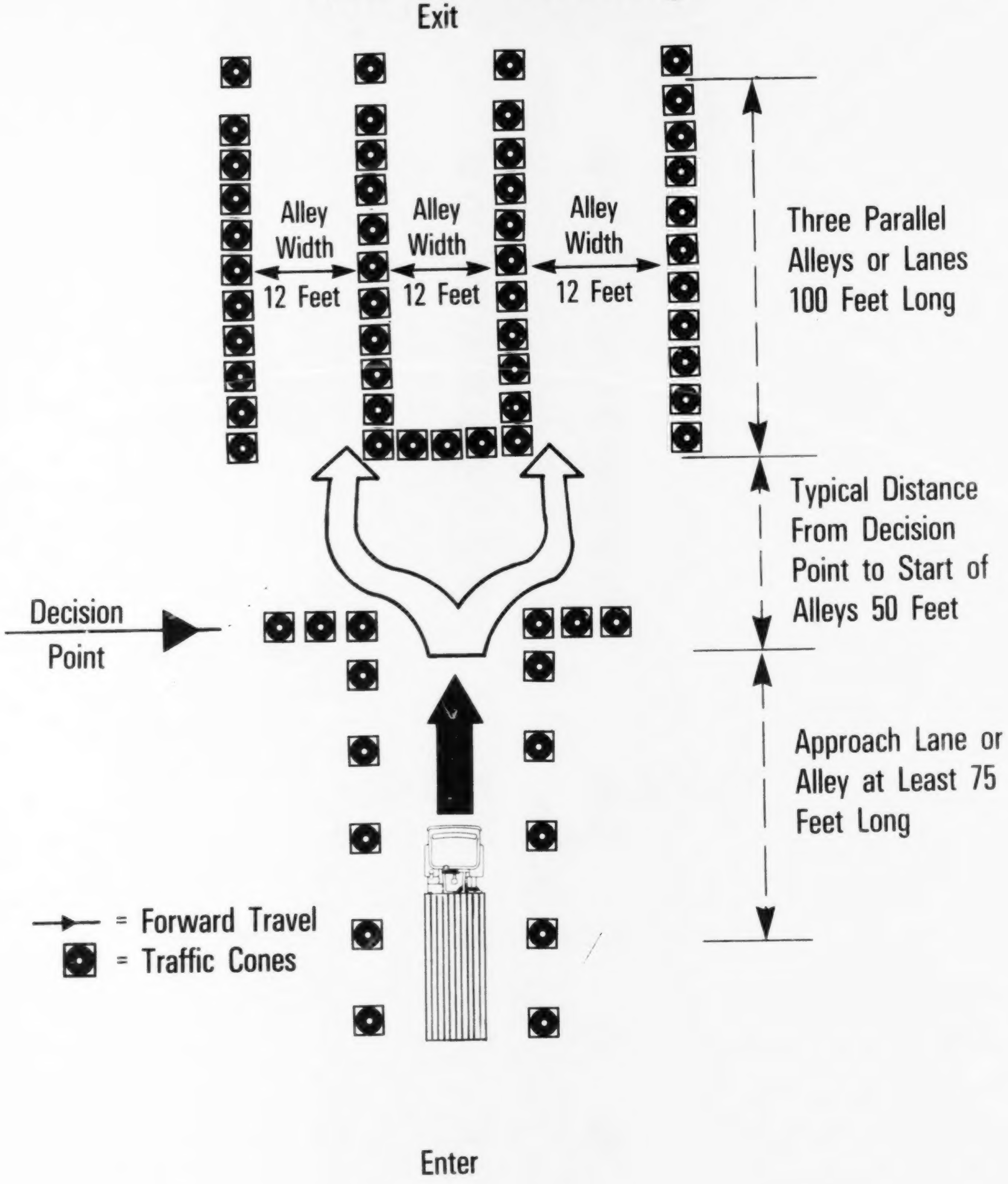
Visual 13

Emergency Stop

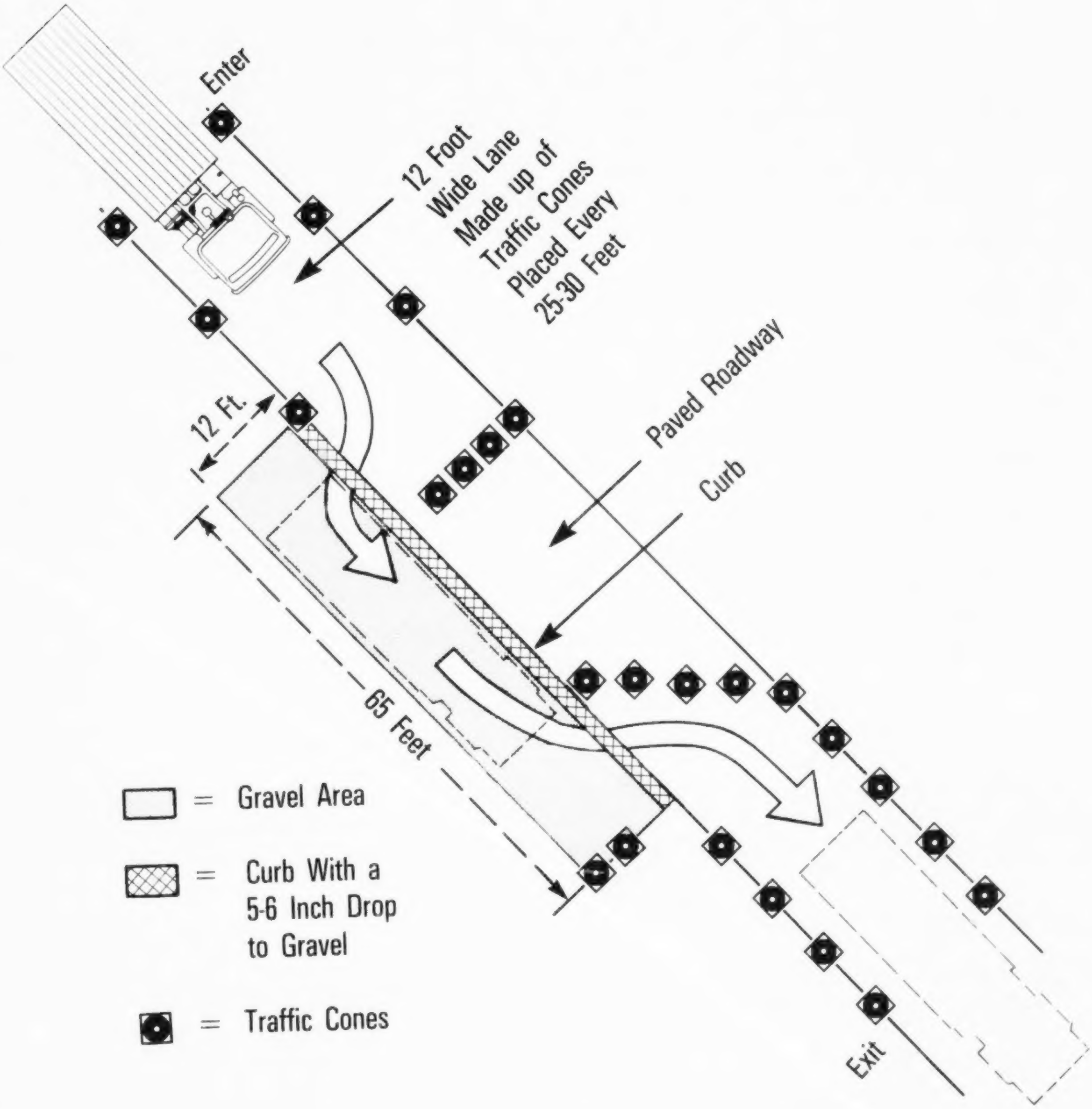

Exit
Alley Width
12 Feet
Braking Alley 100 Feet Long
Typical Distance From Braking Point to Start of Alleys 50 Feet
Brake Application Point
Approach Lane or Alley at Least 75 Feet Long
Enter
= Traffic Cones
= Dashed Line for Measurements
= Travel Forward

Visual 14

Evasive Steering


Exit
Alley Width 12 Feet
Alley Width 12 Feet
Alley Width 12 Feet
Three Parallel Alleys or Lanes 100 Feet Long
Typical Distance From Decision Point to Start of Alleys 50 Feet
Decision Point
Approach Lane or Alley at Least 75 Feet Long
= Forward Travel
= Traffic Cones
Enter

Visual 15


Enter
12 Foot Wide Lane Made up of Traffic Cones Placed Every 25-30 Feet
Paved Roadway
Curb
12 Ft.
65 Feet
Exit
☐ = Gravel Area
▨ = Curb With a 5-6 Inch Drop to Gravel
■ = Traffic Cones

Off-Road Recovery

LESSON 2 EMERGENCY SKILLS (RANGE)

Overview

Time Allotted: 4 hours

Prerequisites: Unit 3.2, Lesson 1

Purpose:

The purpose of this lesson is to develop the students' ability to properly execute a straight line emergency stop, evasive steering and off-road recovery maneuvers in a safe, controlled environment under expert guidance. Additionally students will receive a graphic demonstration of the need to wear seatbelts in order to be able to maintain vehicle control under emergency situations. Each student must receive a minimum of 90 minutes of BTW time (30 minutes in each of the three exercises).

Materials

Instructional Aids

None

Student Material

Emergency Maneuvers Checklist, in Unit 3.2 of Student Manual

Rules for Range Exercises, in Unit 1.1 of Student Manual

Instructor Material

Range Diagrams for Exercises 1, 2 and 3 (at end of lesson)

Equipment

A 5-axle tractor-trailer (preferable a flat-bed trailer)

Radio communication may be provided between the cab of the tractor-trailer and observer students to allow the observers to receive instruction from the instructor in the cab. This would eliminate the need for an assistant instructor to supervise and instruct observers.

Facilities

Facilities must be properly constructed and of adequate size for safe conduct of these exercises.

Technical Note

No instructor should attempt to conduct these exercises, unelss they have had special training in these subjects. Carefully review all requirements for both equipment and facilities in the School Adminstrator's Manual of this curriculum before commencing this lesson.

Content

Activity or Topic	Approximate Time
1. EMERGENCY STOP	60 minutes
2. EVASIVE STEERING	90 minutes
3. OFF-ROAD RECOVERY	90 minutes
	4 hours

1. EMERGENCY STOP (1 hour)

Purpose

The purpose of this exercise is to develop the student's ability to bring the vehicle to a quick, controlled stop during an emergency situation.

Range Layout

The layout must provide an alley, delineated by cones or painted lines, that is 12 feet wide and at least 100 feet long where the vehicle can be brought to a controlled stop. At the head of the alley should be a "braking point," consisting of a flag or clearly identifiable traffic cone, to signal the point at which brakes are to be applied. See the "Emergency Stop" diagram at the end of this lesson.

Directions

1. The exercise will last a total of 60 minutes, each student is to receive 20 minutes BTW emergency stop practice.

2. Drivers will approach the maneuver area (alley). Upon reaching the Braking Point they must apply the brakes and bring the rig to a stop.

3. Each 20 minute session with a student will consist of the following:

   a. One "full lockup" stop at 10 mph.
   b. Three "Stab" braking stops at 10 mph, 20 mph, and 30 mph.

4. The students will rotate from BTW to posts on the range to observe wheel movement for braking pattern. An assistant instructor should be provided to supervise observer students and point out the braking technique employed by the driver (by observing tire rotation) and its effect upon stopping distance.

5. The chief instructor will ride in the vehicle to monitor exercise entry speed and braking technique (i.e., release of brakes long enough to permit wheels to roll).

6. If the student successfully completes the exercise routine prior to the end of the 20 minutes, the additional time may be given to students who are slower to learn.

7. Discuss with students the total loss of control during a full lockup; repeat anouther full lockkup run if student is not convinced of the control loss.

Observation

The instructor will observe the failure to perform the following procedures properly:

Full lockup
Apply brakes until lockup occurs
Maintain pressure

Stab braking
Apply brake fully
Release brake partially when wheels lock
Allow time for brake systems to recover
Wheels must start to roll again
Reapplying too quickly can result in skid
Generally takes about 1/2 - 1 second for brakes to recover
Repeat "stab braking" sequence until vehicle slows sufficiently

The instructor should watch for the following problems:

o Too Rapid Application--Student doesn't allow brake system to recover and restore rolling traction.

o Stiffening at the Wheel--Using a "Whoa Nellie" grip on the wheel resulting in inability to turn wheel quickly enough.

o Cheating on Maneuver--Approaching too slowly or braking too soon.

o Underapplication--If stopping distance does not decrease after repeated runs, students may not be applying maximum braking pressure.

Evaluation

Student performance will be evaluated against the following criteria:

1. Uses minimum stopping distance consistently.

2. Maintains tractor and trailer alignment.

2. EVASIVE STEERING (1 hour 30 minutes)

Purpose

The purpose of this exercise is to develop students ability to perform evasive steering maneuvers. Several different maneuvers will be practiced, including: left and right evasive stter; evasive steer and stop; and controlled brake, evasive steer, brake.

Range Layout

Layout consists of a marker entry way leading to a right or left path from which there is an exit. See Range Diagram, "Evasive Steering."

Directions

This exercise will last a total of 90 minutes, each student is to receive 30 minutes of behind-the-wheel evasive steering practice.

Each 30-minute session with a student will follow the pattern listed:

a. Maneuver 1 (10 minutes) Evasive Steering Right or Left--During this maneuver, the instructor will direct each student to

   (1) On command, accelerate to 30 mph moving toward the barrier of markers.

   (2) On command, steer either to the right or left around the barrier, with no braking.

   (3) Perform the maneuver as smoothly and as quickly as possible.

   (4) Return to start point, repeat until the 10 minutes has elapsed.

b. Maneuver 2 (10 minutes) Evasive Steering with Controlled Brake and Stop--During the maneuver, the instructor will direct each student to

   Steps (1) - (4) of Maneuver 1 are to be followed, except

   (2) After steering right or left, bring the vehicle to a stop as quickly as possible using the controlled braking technique.

c. Maneuver 3 (10 minutes) Brake-Evasive Steer-Stop During the Maneuver--The instructor will direct each student to

   Stops (1) - (4) of Maneuver 1 are to be followed, except

   (2) As soon as the right or left command is given, the student should brake to reduce spped before evasive steering, release brakes and steer, reapply brakes to stop as quickly as possible.

The students will rotate from behind the wheel to position on the range to observe evasive steering techniques.

Instructor will ride in the vehicle to monitor student performance.

Each maneuver wil be performed at 20-25 mph.

Observations

The instructor will observe for failure to perform the following procedures properly:

- Minimize turn
  - Start as early as possible
  - Turn only as much as needed

- Turn quickly
  - Use hand-over-hand technique
  - Each turn approximately 180°

- Avoid braking in turn
  - Could lock wheel
  - Locking wheels during turn could result in loss of control

- Countersteer
  - Must be prepared to countersteer quickly
  - Initiate countersteer as soon as front of trailer clears obstacle

- Brake to stop
  - Stab braking
    - Apply brake partially when tires lock
    - Release brake partially when tire lock
      - Achieves maximum braking while applied
      - Releasing avoids skid, reapply brake when wheels start rolling
      - Allowing time for brake system to recover
      - Wheels must start to roll in order to provide traction
        - Reapplying too quickly can result in skid
        - Generally takes about 1/2 - 1 second for brakes to recover
    - Repeat "stab" braking sequence until vehicle slows sufficiently

Instructor should watch for the following common problems:

Turning the Wrong Way--Students who "guess" at the steer command will turn in the wrong direction about half of the time. Such students should be instructed to approach barrier at a lower speed until the maneuver has been performed correctly.

Failure to perform correctly--Students who continue to have problems with any exercise, should reduce the approach speed in 5 mph decrements. If this does not work, tell the student in which direction to start before approaching the decision point. After the student has mastered this evasive steering, return to the practice of withholding the direction of turn until the decision point has been reached.

Evaluation

Student will be evaluated against the following criteria:

- Does not hit exercise markers.
- Does not keep wheels locked during barking.
- Steers in the correct direction on command.

3. OFF-ROAD RECOVERY (1 hour 30 minutes)

Purpose

The purpose of this exercise is to develop student's ability to perform an off-road recovery maneuver, once the vehicle's wheels have left the road surface. This exercise involves the right wheels and all wheels leaving and returning to the road surface.

Range Layout

This exercise should be performed along the edge of the paved range surface. Along the edge of the range should be provided a gravel surface at least 12 feet in width and 65 feet in length. There should be a drop off of approximatley 5 to 6 inches between the paved and gravel surfaces. Traffic cones should force the vehicle off the pavement at the beginning of the gravel surface and back on to the pavement at the end of the gravel surface. See the Range Diagram "Off-Road Recovery" at the end of the Lesson.

Directions

1. This exercise will last a total of 90 minutes, each student is to receive 30 minutes behind the wheel practice for off-road recovery.

2. Students will approach the off-road recovery area. Upon approaching the barrier across the paved surface, they will steer off the pavement on to the graveled surface. After passing last cone on left, they will return to the paved surface.

NOTE: In an actual driving situation, the failure to come to a complete stop can be extremely dangerous.

3. Each 30 minute session with a student will consist of the following:

   a. Partial (right wheel only) off-road recovery at 10, 20, and 30 mph (approximately 15 minutes).

   b. Complete (all wheels) off-road recovery at 10, 20, and 30 mph (approximately 15 minutes).

   If the student does not perform the run correctly, repeat the run.

4. The students will rotate from behind the wheel to positions on the range to observe recovery techniques being practiced.

5. Instructor will ride in the vehicle to observe and comment on student performance of the recovery exercises.

Observation

The instructor will observe for failure to perform the following procedures properly:

- Drive between the two cones marking entry to exercise area.
- Steer into off-road area as far as required--two or four wheels.

  NOTE: In an actual emergency driver might brake in order to reduce speed before leaving the road. However in this evercise, braking would necessitate higher entry speeds than the range area may permit.

- Keep firm grip on wheel and maintain course. Avoid braking.
- When past last cone on right, steer left sharply.
- As soon as right wheel clears pavement (as sensed by impact of right wheel with the edge of the pavement), steer sharply to the right. Steps 4 and 5 should be one continous activity.

Instructor should watch for the following common problems:

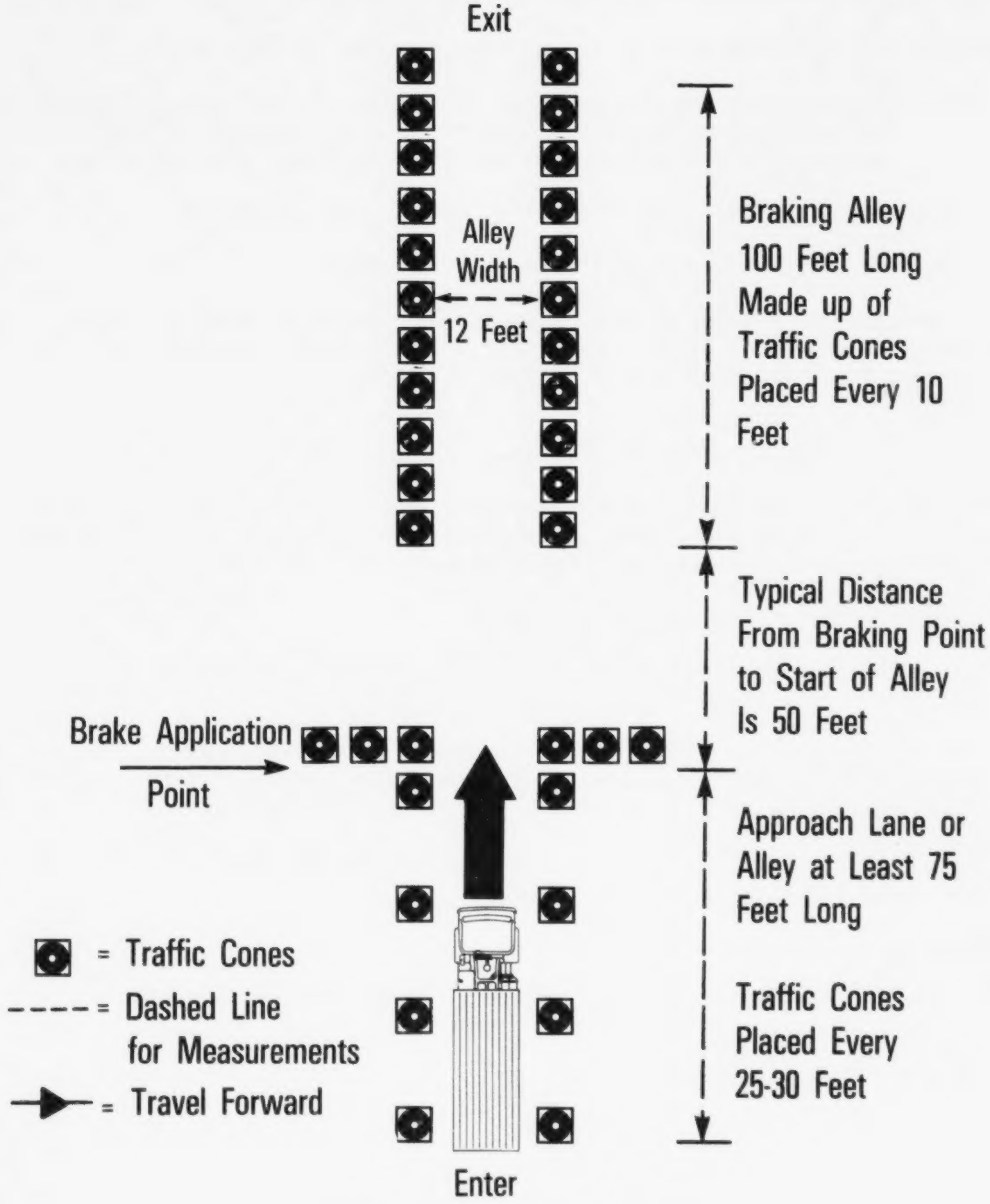
- Students not turning far enough up on to the gravel surface to allow the front wheel next to the pavement edge to turn, with the result that the tire scrubs along the edge of the pavement.
- Braking while on the gravel surface.
- Edging back on the road rather than turning sharply, with the result that the tire scrubs along the edge of the pavement.
- Not countersteering quickly enough--making evasive and countersteering separate responses rather than on continuous response--with the result that the vehicle cuts across the proper lane into the next lane.
- Over countersteers, with the result that the vehicle drops back off of the paved surface.

Evaluation

The student's performance will be evaluated by the following criteria:

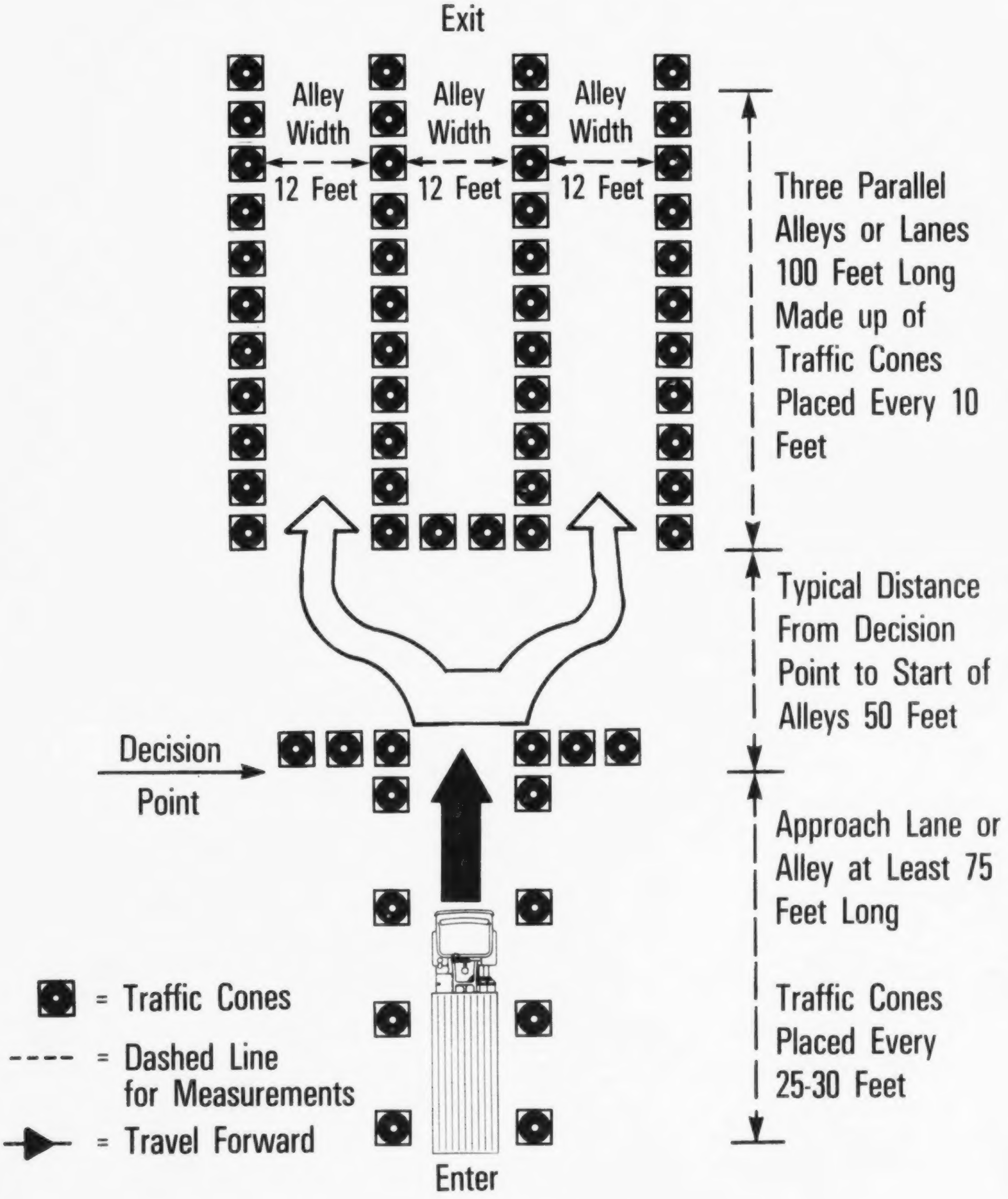
1. Does not lock brakes.
2. Does not knock over any cones.

Range Diagram—Exercise 1


Exit
Alley Width
12 Feet
Braking Alley 100 Feet Long Made up of Traffic Cones Placed Every 10 Feet
Typical Distance From Braking Point to Start of Alley Is 50 Feet
Brake Application Point
Approach Lane or Alley at Least 75 Feet Long
Traffic Cones Placed Every 25-30 Feet
= Traffic Cones
---- = Dashed Line for Measurements
= Travel Forward
Enter

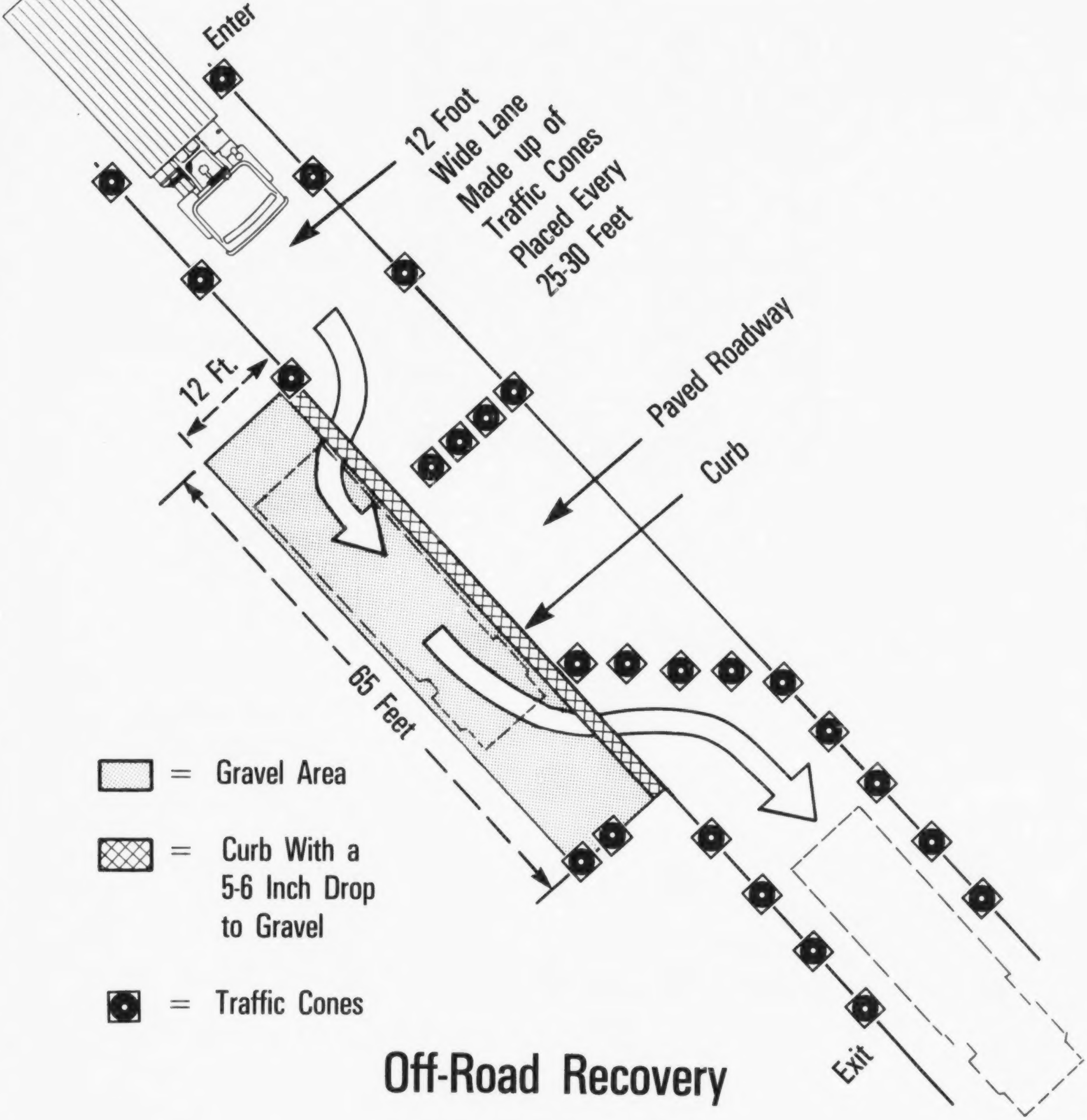
Emergency Stop

Range Diagram—Exercise 2


Exit
Alley Width
12 Feet
Alley Width
12 Feet
Alley Width
12 Feet
Three Parallel Alleys or Lanes 100 Feet Long Made up of Traffic Cones Placed Every 10 Feet
Typical Distance From Decision Point to Start of Alleys 50 Feet
Approach Lane or Alley at Least 75 Feet Long
Traffic Cones Placed Every 25-30 Feet
Decision Point
= Traffic Cones
---- = Dashed Line for Measurements
= Travel Forward
Enter

Evasive Steering

Range Diagram—Exercise 3


Enter
12 Foot Wide Lane Made up of Traffic Cones Placed Every 25-30 Feet
12 Ft.
Paved Roadway
Curb
65 Feet
Exit
▨ = Gravel Area
▩ = Curb With a 5-6 Inch Drop to Gravel
● = Traffic Cones

Off-Road Recovery

UNIT 3.3
SKID CONTROL AND RECOVERY

UNIT 3.3 SKID CONTROL AND RECOVERY

PURPOSE

The purpose of this unit is to teach the causes of skids and jackknifing accidents. Skid prevention and recovery is discussed in the classroom, followed by actual hands-on practice on the skid pan.

OBJECTIVES

Performance Objectives

The student must be able to

- maintain directional control while operating over a slippery surface.
- bring tractor-trailer to a stop in the shortest possible distance while maintaining directional control when operating on a slippery surface.
- recover from incipient tractor or trailer skids induced by snow, ice, water, oil, sand, wet leaves or other slippery surfaces.

Knowledge Objectives

The student must know

- the role of skid control in preventing accidents.
- skid dynamics, including friction, wheel load and force
- causes of skidding
- the characteristics of a tractor jackknife, trailer jackknife, front wheel skids and all wheel skids.
- skid recovery procedures

Skill Objectives

The student must be able to

- countersteer out of a skid in a way that will regain directional control and not produce another skid.
- operate brakes properly to provide maximum braking without loss of control.
- judge maximum safe speed for slippery surface conditions.

Attitude Objectives

Students must believe that

- most skids are preventable.
- skids can occur at any speed.
- it is possible to recover from skids if they are detected and corrected promptly.

LESSONS

Lesson 1.	**Techniques of Skid Control and Recovery (Classroom)**	**1 hour 15 minutes**
Lesson 2.	**Skid Control and Recovery Exercises (Range)**	**7 hours 45 minutes***

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* Optional

LESSON 1 TECHNIQUES OF SKID CONTROL AND RECOVERY (CLASSROOM)

Overview

Time Allotted: 1 hour 15 minutes

Prerequisites: Unit 3.2

Purpose:

The purpose of this lesson is to discuss conditions that produce skidding, demonstrate and describe the major types of skids, and present procedures for recovering from skids. The lesson will end with a preview of range maneuvers to be performed, and safety precautions to be observed.

Materials

Instructional Aids

Visuals 1 - 10

Student Material

Special range safety rules for skid control and recovery

Instructor Material

Model (toy) tractor-trailer modified so that any individual wheel may be locked up for skid demonstration purposes.

A "sliding board" made of plastic or polished wood, approximately 2 feet by 3 feet for use in demonstrating skids or a smooth table top will suffice.

Equipment

Instructors should carefully review the requirements for vehicles to be used in skid pan training contained in the "Equipment and Materials" section of the School Administrators Manual.

Content

Activity or Topic	Approximate Time
1. ROLE OF SKIDDING IN ACCIDENTS	3 minutes
2. SKID DYNAMICS	17 minutes
3. TRACTOR-TRAILER SKIDS	35 minutes
3. SKID RECOVERY	10 minutes
4. RANGE PROCEDURES	10 minutes
	1 hour 15 minutes

1. ROLE OF SKIDDING IN ACCIDENTS (3 minutes)

A skidding vehicle is a vehicle out of control.
The major causes of all skids is excessive speed for conditions.
All drivers have the responsibility to maintain a constant awareness of road surface conditions and adjust speed accordingly.

Jackknifes--contributed to almost 11 percent of all accidents and 29 percent of those accidents where only the tractor-trailer itself was involved

Skidding contributes to
- Running off the road
- Overturning
- Collisions with other vehicles
  - Truck skids into other vehicle in 2 percent of collisions
  - In many other accidents, skidding prevents collision avoidance

2. SKID DYNAMICS (7 minutes)

Vehicle Control Factors

Skids occur when there is an imbalance among vehicle control factors

Factors that affect vehicle control include:
- Friction (traction)
- Wheel load
- Forces of motion

Friction

Resistance between tires and pavement surface defined as traction
Importance
- Means by which the motion of the vehicle is controlled

Acceleration
- Friction between rotating tire and pavement causes vehicle to move
- This form of friction called "traction"

Steering
- Friction of tire against pavement resists lateral motion This friction controls direction vehicle moves

Braking
- Friction of brake system resists turning of wheels
- Friction of tire against pavement surface resists motion of vehicle

Visual 1 Forms of Traction

Traction (friction) commonly divided into three forms
- Static Traction
- Rolling Traction
- Sliding Traction

Static Traction

- Friction between two stationary surfaces
    - Tires of parked vehicle on pavement
    - Rolling tire also has static friction to a lateral motion
- Static friction offers the greatest resistance to motion

Rolling Traction

- The friction offered by one surface rolling over another
- The friction of a rotating tire in the direction the tire is moving
- Not as much resistance as static friction, but more than sliding friction

Sliding Traction

- The friction of one surface sliding across another
- Occurs when the forces acting upon surfaces exceed the friction between them, such as a
    - Locked wheel
        - Locks from overbraking Wheel may slide in any direction
    - Turning wheel
        - Excessive outward force causes wheel to slide sideways
        - Wheel continues to turn
    - Sliding friction offers less resistance than rolling friction

Remove Visual

Wheel Load

- The downward force of weight upon the wheel
- The greater the wheel load, the greater the resistance for any given coefficient of surface and tire friction
- Wheel load determined by
    - Weight of vehicle (tractor, trailer)
    - Weight of load
    - Distribution of load

Forces of Motion

- Force is a function of the weight and its speed
    - Weight--the greater the truck weight--the greater force it generates
    - Speed--the faster the truck is moving--the more force it generates
- Causes of skidding
    - Skidding while braking
        - Forces of motion exceed the friction of the braking system and the tire against the pavement
        - Vehicle skids rather than stops
    - Skidding while steering
        - Forces of motion exceed the friction of the (turned) tire against the pavement
        - Vehicle continues in the direction it was moving rather than turning

Visual 2 Types of Skids

Three Basic Types of Skids

Braking
Turning
Acceleration

Braking

Wheel Locks

- Results from overbraking including excessive application of service brakes, engine exhaust brakes, or retarder; excessive downshifting or sudden drop in acceleration
- Wheel stops rotating

Tire Slides

- Force from weight and acceleration of vehicle exceeds tire friction on pavement surface
- Locked wheel slides along pavement creating a braking skid

Stopping Distance Increased

- Sliding friction offers less resistance to motion of vehicle than rolling friction
- Lowered resistance increases stopping distance
- Stopping distance is greater for locked wheels than rolling wheel

Loss of Control

- Locked wheel is free to slide in any direction
- Vehicle skids out of control
  - Straight ahead--entire rig can continue to skid in the original direction of travel
  - Sideways--on a high crown road, the entire rig can slide sideways (on to shoulder or into a ditch)
  - Jackknife--one set of wheels can continue to go straight ahead while the other goes sideways, resulting in a tractor or trailer jackknife (to be discussed later)

Turning

Turning Forces

- When vehicle turns, centrifugal force tends to make the vehicle continue in the direction it was originally going
- As a result of the centrifugal force, a vehicle tends to slide outward in a turn
- Centrifugal force increases with vehicle speed and rate of turn

Turning Skids

- If rate of speed or rate of turn are too great, centrifugal force exceeds static friction
- Static becomes sliding friction, and tire moves sideways
- If wheels lock up, there is even less friction and vehicle tends to move sideways even faster

Accelerating

Acceleration skid occurs when the amount of torque (rotary force) applied to the drive wheels exceeds the friction between the wheels and the pavement

When friction is exceeded, the drive wheels are free to spin

Rolling friction becomes sliding friction

Tire will not propel vehicle
- Wheel spins but vehicle does not move
- Spinning continues until the driver stops accelerating and the force no longer exceeds the level of friction

Tire also free to move in any direction
- Drive wheels slide sideways
- Rear of tractor "spins out"

Frequently called a "power skid"

Visual 3 Conditions That Produce Skids

Preventing Skids

It is better to prevent skids than try to recover from them

Save operating practices discussed earlier help to prevent skids

Adjusting speed to conditions (Unit 2.3)
- In curves--
  - Reduces outside force
  - Reduces chances of cornering skid
- Limited sight distance
  - Reduces need for sudden stop
  - Reduces chances of braking skid

Maintaining adequate following distance (Unit 2.4)
- Reduces chances of having to stop or turn quickly
- Reduces chances of braking and cornering skids

Slippery surfaces (Unit 2.6)
- Avoiding excessive speed or quick turns
- Reduces chances of braking, cornering, or acceleration skids

3. TRACTOR-TRAILER SKIDS (35 minutes)

Classification

Tractor-trailer skids classified primarily upon what happens to vehicle and trailer

Four major types of skids
- Trailer jackknife
- Tractor jackknife
- Front wheel skid
- All wheel skid

Visual 4 Trailer Jackknife

Trailer Jackknife (Trailer Wheel Skid)

Demonstration

- Instructor carries out the following:
  - "Locks" trailer wheels of model tractor-trailer
    - Tape upper part of tire to trailer body
    - Drill hole into tire and body and insert pin
  - Places sliding board on a table top and raises one end until sliding board at an angle of approximately 45° to the top of the table
  - Asks students what will happen when vehicle is released
  - Releases vehicle

Explanation

- Rear wheels locked
  - Can't turn
  - Overcome surface friction
  - Change from rolling to sliding friction
- Trailer swings
  - Trailer wheels--sliding friction
  - Truck wheels--rolling friction
  - Rear tires less friction than front
  - Rear swings out to overtake front

Cause

- Overbraking
- Excessive cornering

Overbraking

- Overapplication--driver application of brake excessive for surface conditions
  - Foot brake
    - Independent trailer brake (which should not be used for stopping)
  - Brake problem
    - Air system--too much pressure to trailer wheels
    - Mechanical adjustment--not properly adjusted in relation to other wheels
    - Linings--extremely worn trailer brake linings can cause brake seizure
    - Load--light trailer load
      - Reduces wheel load
      - Produces friction loss

Excessive Cornering

- Enters curve too fast for surface conditions
  - Rolling friction overcome by centrifugal force rather than by locked brake
  - Rear of trailer continues in same direction while tractor and front of trailer turn

- Both effects can occur
    - Vehicle overbraked while cornering
    - Both forces combine to overcome friction

Prevention

- Inspection
    - Air system
    - Brake adjustment
- Adjust speed to surface conditions and curvature
    - Reduces tendency to overbrake
    - Reduces speed in curves
- Avoid braking in curves
    - Brake before entering curve
    - If speed excessive, better to "ride-it-out" than brake

Visual 5 Tractor Jackknife

Tractor Jackknife (Drive Wheel Skid)

Demonstration

- Instructor carries out the following:
    - Locks "drive" wheels on model tractor-trailer
    - Places vehicle atop sliding board
    - Asks students what will happen when vehicle is released
    - Releases vehicle

Explanation

- Tractor drive wheels lose friction
    - Drive wheels have less resistance than front wheels
    - Drive wheels attempt to overtake front wheels
    - Rear of tractor tends to swing out

- Front of trailer pivots
    - Tractor pulls fron of trailer outwards
    - Trailer pushes rear of tractor outward
    - Results in jackknife

Causes

- Tractor drive wheels overcome friction because of:
    - Lockup
    - Over acceleration
    - Trailer override

- Locked Drive Wheels--can result from any of the following:
    - Over application of brakes--could affect drive wheels first
    - Downshift--engine braking could cause lockup on slippery surface, particularly with engine braking device
    - Sudden release of accelerator on slipper surface
    - Load imbalance--could reduce drive wheel loading
    - Brake malfunction
        - Air system
        - Misadjustment
    - Poor tread on drive tires

Over Acceleration

- Results from over application of accelerator relative to gear and vehicle speed
- Referred to as "power skid"
- Most likely to occur under the following conditions:
  - High horsepower/torque engine
  - Heavily or improperly loaded trailer (resists forward motion)
  - Slippery surface
- Not as common as locked drive wheel skid

Trailer Override

- During braking, cargo load may push trailer against tractor
  - Pushes rear of tractor outward
  - Creates tractor jackknife
  - Aggravates a drive wheel jackknife
- Most likely to occur if
  - Pavement is slippery
  - Trailer is heavily loaded
  - Cargo is not properly distributed or secured

Prevention

- Avoid overbraking, over acceleration, sudden downshift
- Inspect brake system, tire tread
- Load properly
- Secure cargo

Visual 6 Front Wheel Skid

Front Wheel Skids

Demonstration

- Instructor carries out the following activities:
  - Locks front wheels of model-tractor
  - Places model at the top of the sliding board
  - Asks class what will happen when the vehicle is released
  - Releases vehicle

Explanation

- Model vehicle continues in a straight line
  - Front wheels--sliding friction
  - Rear wheels--rolling friction
  - Front wheels tended to move faster than rear wheels
  - Vehicle continues in straight line
- Lack of front wheel friction also would reduce ability to steer
  - Steering response may be sluggish or nonexistent
  - May fail to negotiate corner or curve
  - Could slide laterally on a high crown road

Causes

- Reduced front wheel friction
- Can result from
  - Excessive load on fifth wheel
    - Improper loading
    - Forward weight shift when braking
  - Lack of tread on front tire
  - Hydroplaning
  - Oversteering (in combination with the above)
  - Brake system malfunction
    - Air system
    - Brake adjustment
  - Improper use of brake limiting valve

Prevention

- Proper loading
- Inspect tires, front wheel alignment, suspension system
- Use brake limiting valve appropriately
- Reduce speed on wet pavement
- Fifth wheel lubrication

Visual 7 All Wheels Skid

All Wheels Skids

Demonstration

- Instructor carries out the following:
  - Locks all wheels of model tractor-trailer
  - Places vehicle atop sliding board
  - Asks students what will happen when vehicle is released
  - Releases vehicle

Explanation

- All wheels locked
  - Wheels cannot turn
  - Overcome surface friction
  - Change from rolling to sliding friction
- Rig continues generally in straight line
  - All wheels have approximately the same amount of friction
  - All wheels continue at the same rate
  - Vehicle remains in straight line
- Driver loses control of steering
- Vehicle can skid offroad
  - High crown
  - Curve
- Infrequent type of skid

Causes

- Two major causes
  - Overbraking
  - Slippery surface

- Overbraking
    - Hard braking could cause all wheels to lock
    - One set of wheels will generally lockup first

- Slippery Surface
    - Light brake pressure can cause wheel lockup
    - Snow, ice surfaces slippery enough

Prevention

- Avoid excessive braking on extremely slippery surface
- If necessary to brake, use "stab" braking to maintain control

Remove Visual

Summary of Skid Prevention

- Most of the methods have been discussed in previous units
    - Managing speed
    - Managing space
    - Driving in extreme conditions
- Basic methods of skid prevention
    - Control adjustment
    - Speed/space adjustment

- Control Adjustment
    - Most skids result from overcontrol
        - Overbraking
        - Oversteering
    - Generally occurs when pavement is slippery
        - Dry pavement permits harder cornering and braking maneuvers than slippery surfaces
        - Surface slippery, vehicle forces (weight and speed) overcome surface friction
    - Adjust control to conditions
        - Avoid quick braking or quick turns on slippery pavements
        - Try to "ride it out" until firm pavement is available
        - If it is necessary to turn or brake, do no more than is absolutely necessary
        - When quick stop is necessary, use controlled or "stab" braking procedure

- Adjust Speed/Space
    - Overbraking and oversteering usually the result of poor speed/space management
    - Reducing speed and allowing more space reduces need for quick turning/braking
    - Review precautions discussed in earlier lessons
        - Reduce speed for slippery pavement
            - Wet pavement
            - Snow
            - Ice
        - Allow more following distance when pavement is slippery

AntiJackknife Devices

Purpose

- Restrict trailer swing
  - Prevent damage
  - Don't prevent skidding

Two Basic Types

- Fifth wheel devices
- Cable devices

  - Fifth Wheel Devices
    - Operation
      - Construction of fifth wheel restricts rotation of kingpin
      - Limits trailer swing less than 90°
    - Advantages
      - Prevents collision between trailer and cab
      - Automatic--requires no action on the part of driver
      - Device mounted on tractor; allows any trailer to be used
    - Disadvantage
      - Doesn't actually prevent jackknife

  - Cable Devices
    - Operation
      - Cables connected from trailer to tractor
      - Actuated by hard braking
      - Prevent trailer swing once actuated
    - Advantages
      - Keeps trailer and tractor in line
      - Prevents jackknife
    - Disadvantages
      - Hard braking conflicts with skid recovery
        - Prevents use of controlled braking
        - Aggravates skid
      - Mounted on trailer; requires a separate device for each trailer

4. SKID RECOVERY (10 minutes)

Visual 8 Skid Recovery

Almost all skids are corrected by the same general responses:

- Counter Steering
- No Braking
- No Accelerating
- Clutch Disengagement

Speed Control

Most skids induced by attempt to change speed too abruptly for conditions:

- Overbraking
- Over acceleration
- Downshifting

First response in any skid should be to control the speed of the vehicle by eliminating overbraking, over acceleration, or downshifting

Overbraking

- Remove foot from brake immediately
  - Restores rolling friction
  - Eases skidding
  - Restores directional control
- Do not apply independent trailer brake
  - Myth: Application of trailer brake and slight acceleration in a jackknife will "straighten out the rig"
  - If the trailer has started to jackknife, application of trailer brake can activate skid
    - It is very difficult to control independent trailer brake well enough to prevent trailer wheel lockup when trailer is already staring to jackknife
    - Locking up trailer wheels will only aggravate the jackknife
- If overbraking resulted from downshifting:
  - Depress clutch quickly to remove engine braking
  - Use foot brake to reduce speed since it gives more precise control than downshifting

Over Acceleration

- Ease off accelerator
- Abrupt removal could accentuate skid
- Depress the clutch pedal to disengage the clutch
- Acceleration (power) skids don't require as quick a response as braking skids
  - Slower vehicle response
  - Generally not as hazardous

Corrective Steering

In a tractor jackknife, corrective steering is needed to put the tractor back on course

Steer in the direction the vehicle is to go

- This is the learned "natural" response
- It will generally happen automatically
  - Exception: If there is some obstruction (e.g., telephone pole) in the direction the vehicle should be turned, the driver may try to steer away from it
  - This causes the rear of tractor or trailer to swing into the object the driver is trying to avoid
  - Driver actually needs to steer toward the object initially in order to straighten out the rig and avoid the object

Oversteer
- On a slippery surface it is necessary to oversteer, i.e., to turn beyond the intended path of travel
- Low friction necessitates oversteering
- If the driver does not oversteer, the skid will not be stopped

Countersteering

Low friction makes vehicle slow to respond

As vehicle resumes correct course, driver must countersteer early in order to avoid "overshoot"

Overshoot occurs when countersteer is initiated too late
- Vehicle continues to turn beyond intended path
    - Could spinout completely
    - If it does not spin out immediately, each correction may get worse until vehicle spins out

Continue countersteer until vehicle is in a straight path
- Continued countersteering produces "fishtailing"
- Each countersteer should get smaller until vehicle assumes straight course

Braking to Stop

Once vehicle is straight, it can be braked to a stop

Use "stab" braking technique discussed in Unit 3.2
- Apply brake hard
- Release brake
- Wait until wheels start to roll again
- Reapply brakes
- Repeat cycle until vehicle stops

Most effective way to stop
- Maintains rolling friction
- Shortest controlled stopping distance
- Maintains directional control

4. RANGE PROCEDURES (10 minutes)

NOTE: The Range Procedures should be previewed briefly. Detailed instructions in carrying out range exercises will be provided by the instructor to each student driver just prior to the exercise. The purpose of this preview is primarily to apprise students of the emergency procedures that will be employed during range exercises in in order that (1) students can review and mentally practice in advance, (2) observers can understand what is going on inside the vehicle as each exercise is performed.

Maneuvers

All maneuvers will be performed on a surface that has been wetted in order to lower the surface friction and produce skids from which students may recover.

Tractor Skid

This exercise will take place in an open area. Since there is no path to be followed, no traffic cones or other markings will be provided.
Student applies brakes to lock tractor wheels
Exercise is intended to provide the experience of an uncontrolled skid

Visual 9 Controlled Braking

Tractor Stop

Student does the following:
- Enters approach path as indicated in visual (pavement along entry path will be dry)
- Begins braking at the Braking Point
- Steers to maintain straight path
- Stab brakes to stop

Visual 10 Turn and Controlled Braking

Tractor Stop/Turn

Student performs the following:
- Enters approach path as indicated in visual
- Determines which path to take at the Decision Point from the directions given by the instructor
- Stabs brakes one time
- Turns around obstacle in the directions given by the instructor
- Stabs brakes to stop

Visual 9 Controlled Braking (Repeat)

Tractor-Trailer Stop

Same as Tractor Stop except that a trailer will have been coupled to the tractor
- Braking response may be different
- Student may experience jackknife
- Antijackknife device wil prevent damage

Visual 10 Turn and Controlled Braking (Repeat)

Tractor-Trailer Stop/Turn

Same as Tractor Stop/Turn except that a trailer will have been coupled to the tractor
- Different braking response
- Jackknife

Range Safety Rules

(Refer students to Range Safety Rules in Student Material while discussing the rules below.)

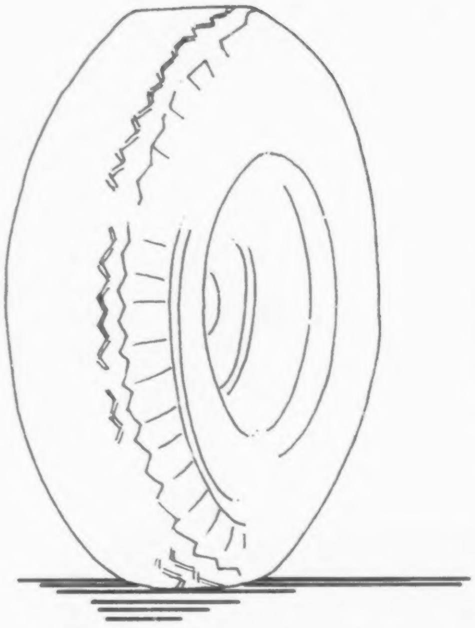
- Don't enter maneuver area until it is clear of all vehicles
  - Student driver may not be able to control the direction of the vehicle
  - If any vehicles already in the maneuver area, may not be able to manuever out of the way of the student's vehicle

- If the vehicle is sliding out of control
  - Keep brakes fully applied
  - Dry pavement beyond skid pan will stop vehicle

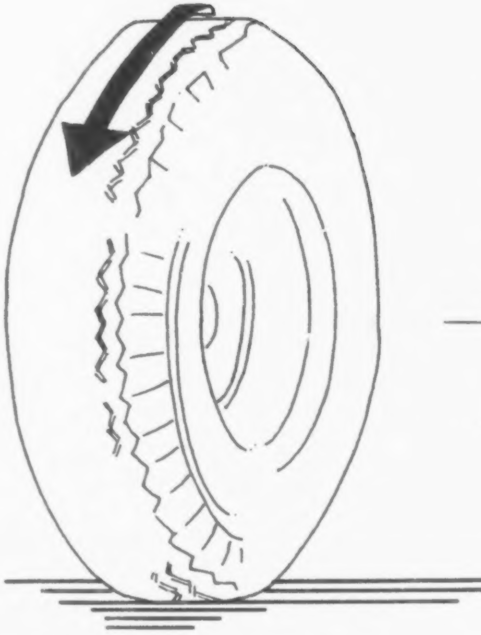
- Only driver and instructor in cab
  - Driver needs plenty of room in cab
  - Observers can see what's happening better from outside

- Observers stay where assigned by instructor
  - Must remain upstream of entry to skid pan
  - Rig may slide sideways due to slope of skid pan (for drainage)

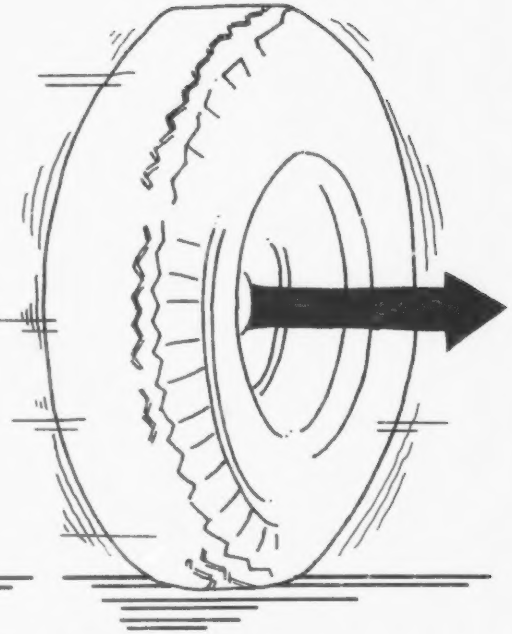
Forms of Traction



Static Traction

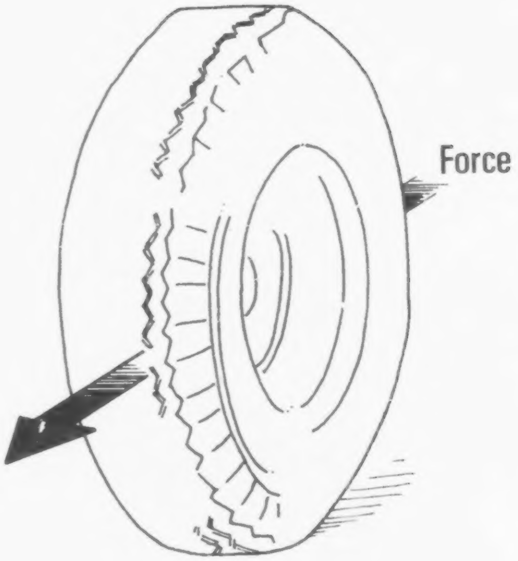


Rolling Traction

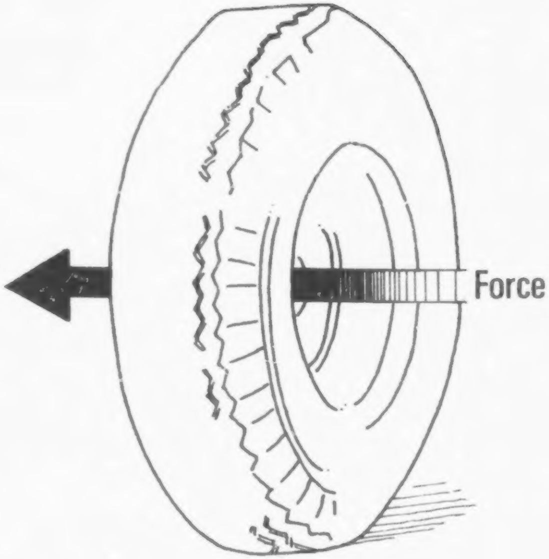


Sliding Traction

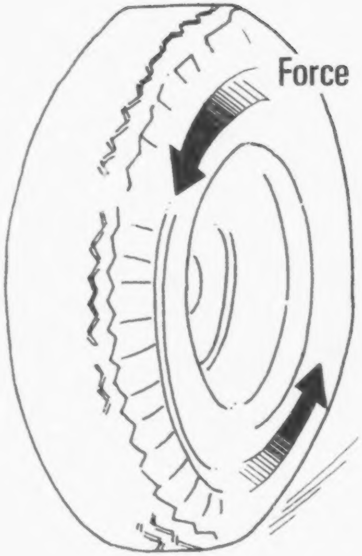
Types of Skids



Braking



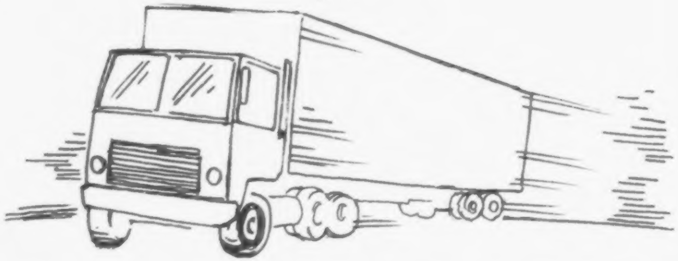
Turning



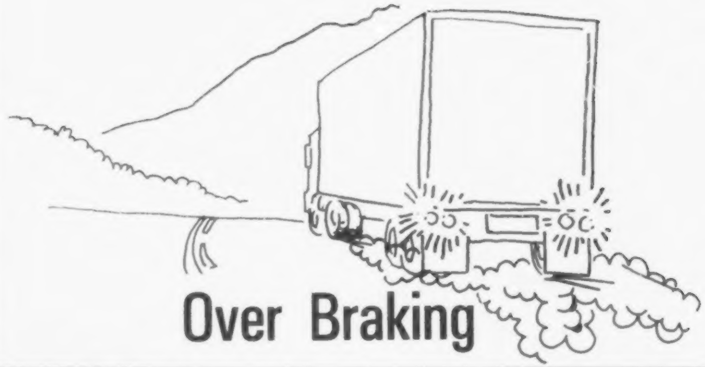
Acceleration

Conditions That Produce Skids

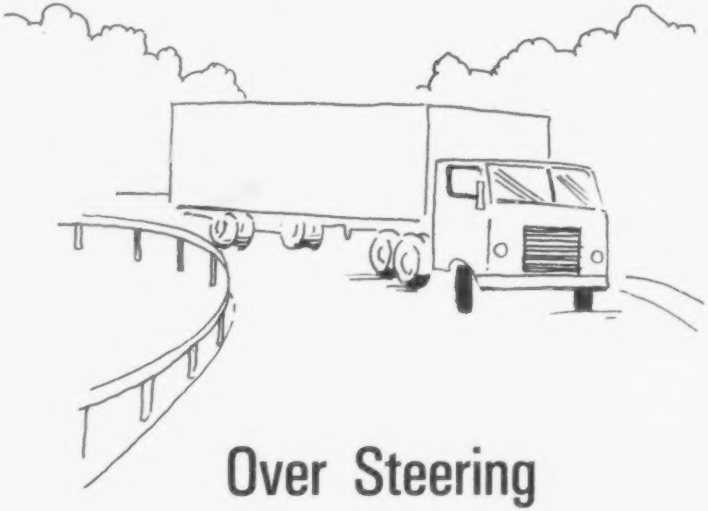
Speed



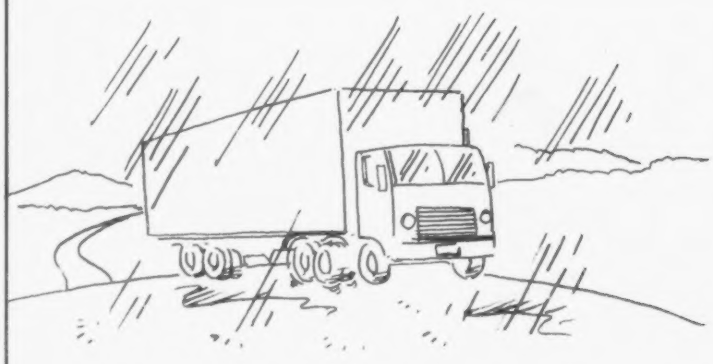
Too Fast for Conditions



Over Braking

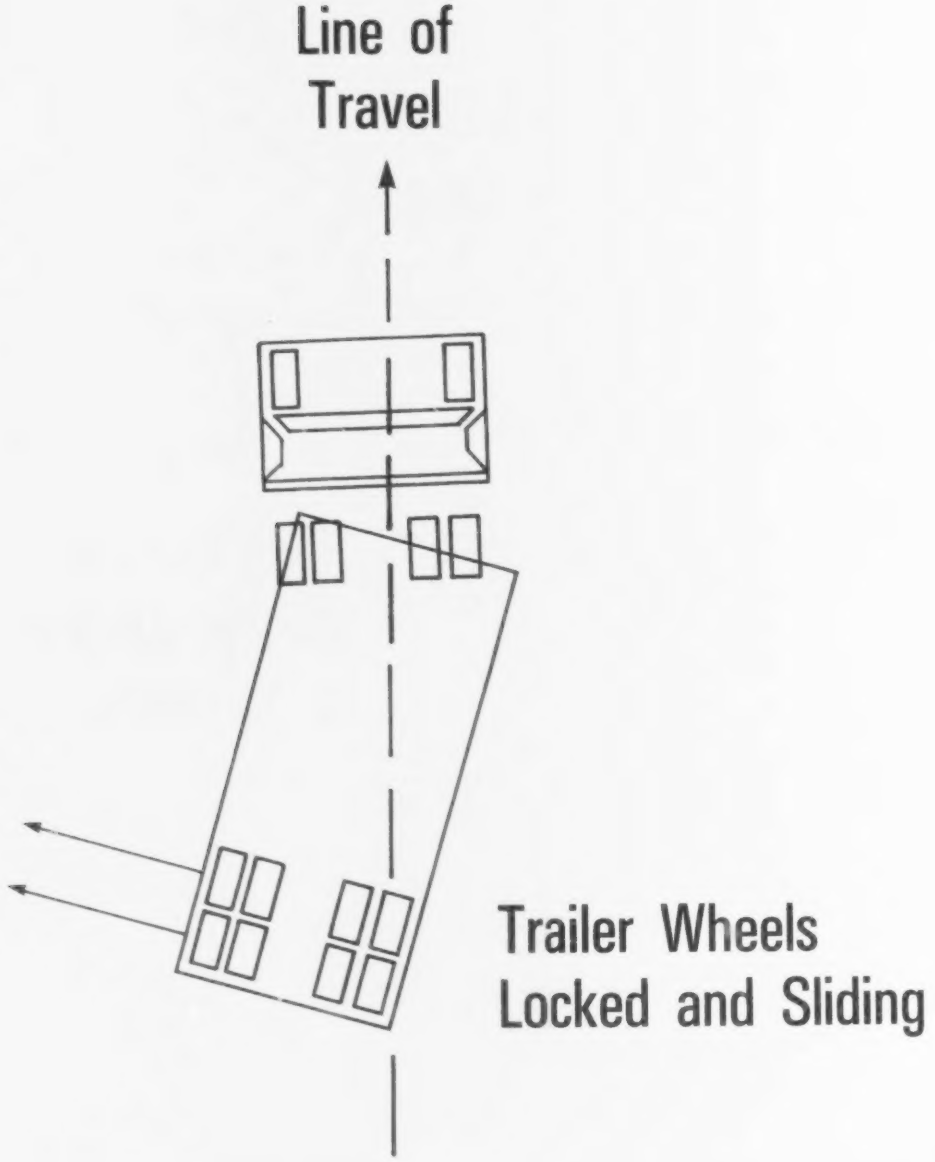


Over Steering



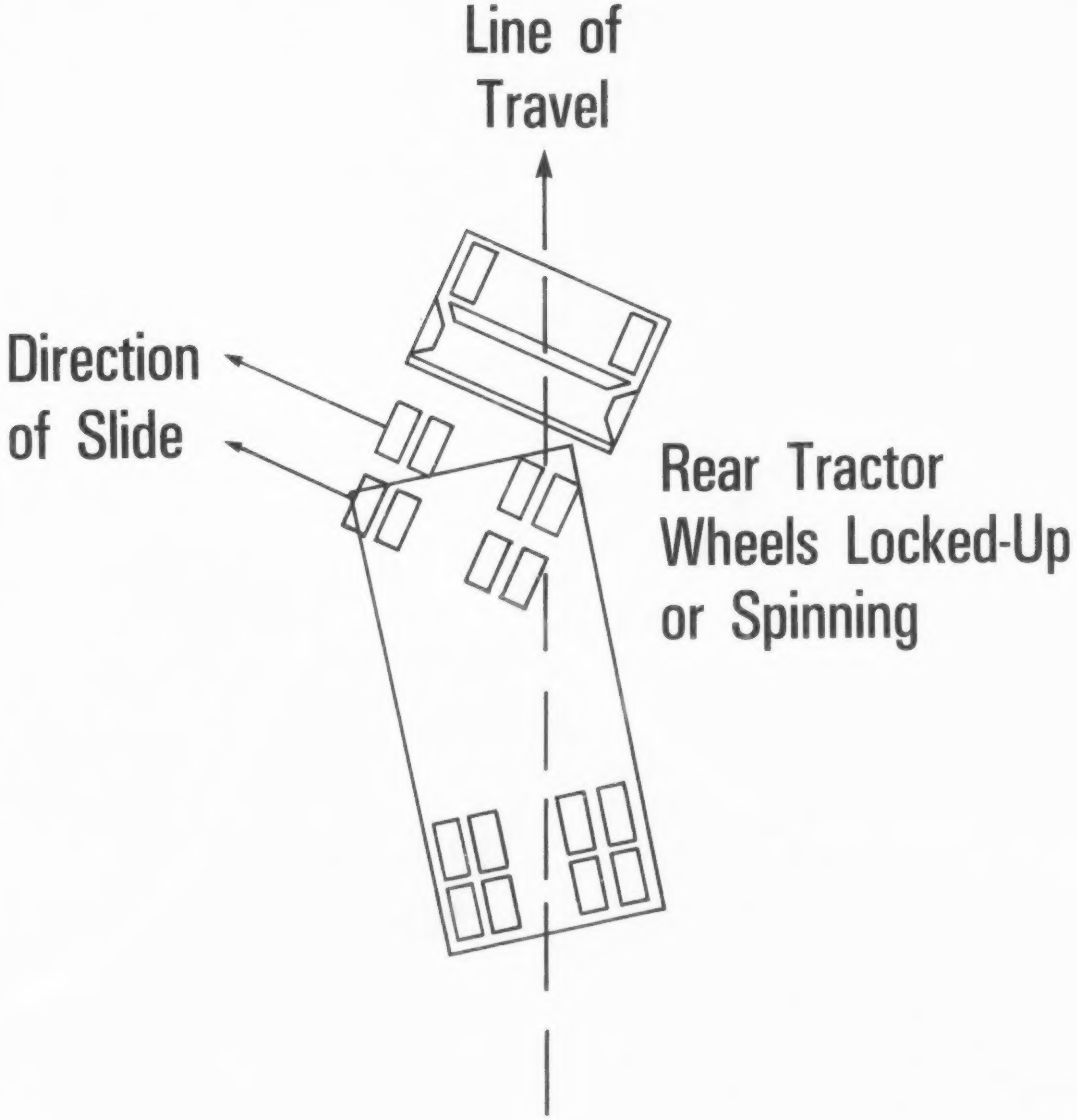
Over Accelerating

Trailer Jackknife


Line of Travel
Trailer Wheels Locked and Sliding

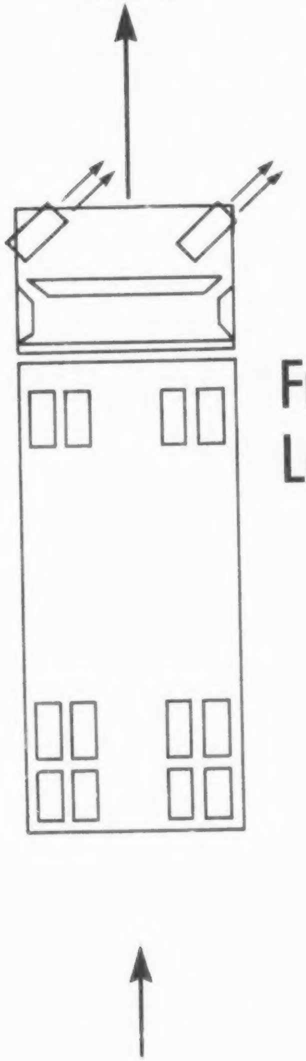
Visual 5

Tractor Jackknife


Line of Travel
Direction of Slide
Rear Tractor Wheels Locked-Up or Spinning

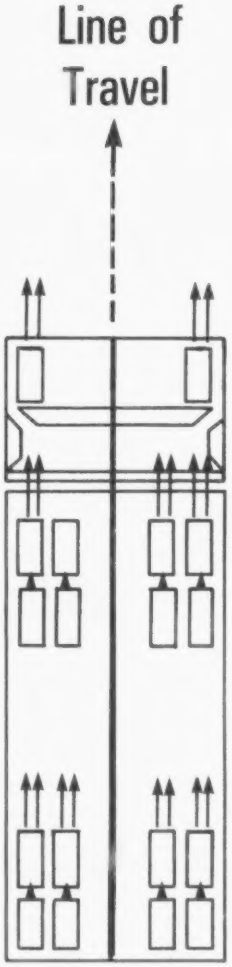
Visual 6

Front Wheel Skid


Line of Travel
Front Wheels Locked-Up and Sliding

Visual 7

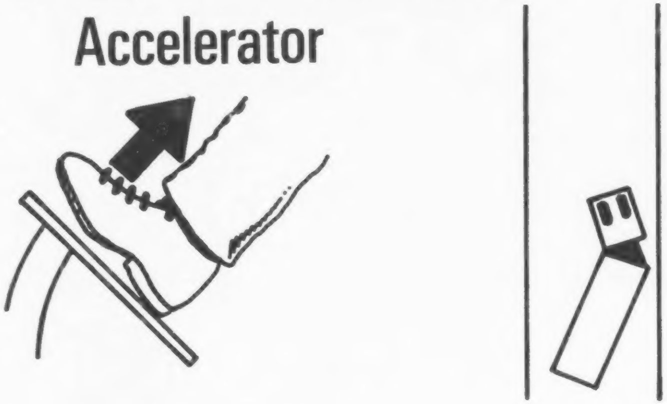
All Wheel Skid


Line of
Travel

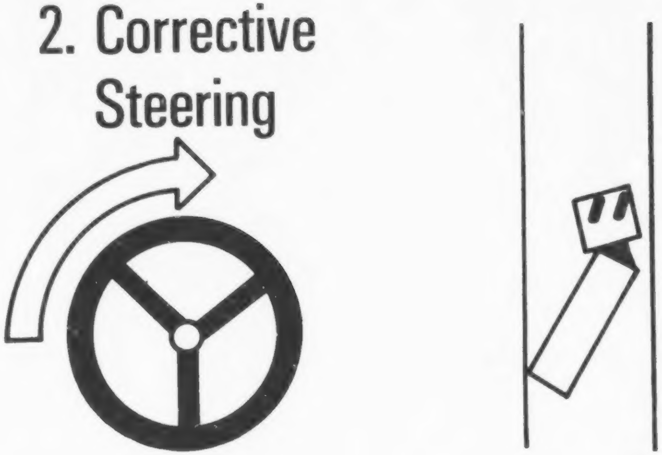
All Wheels Locked-up and Sliding

Skid Recovery

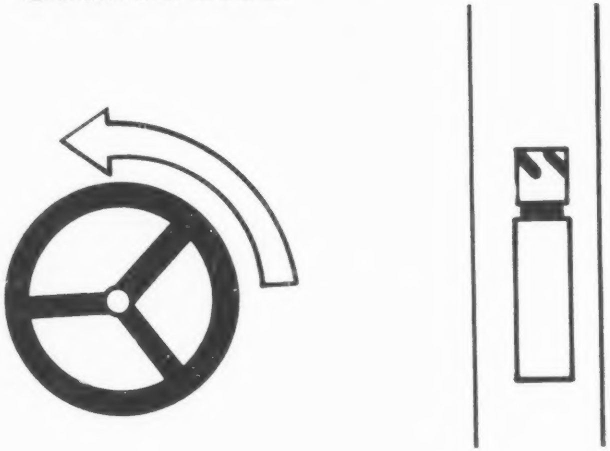
1. Get off Brakes and Accelerator



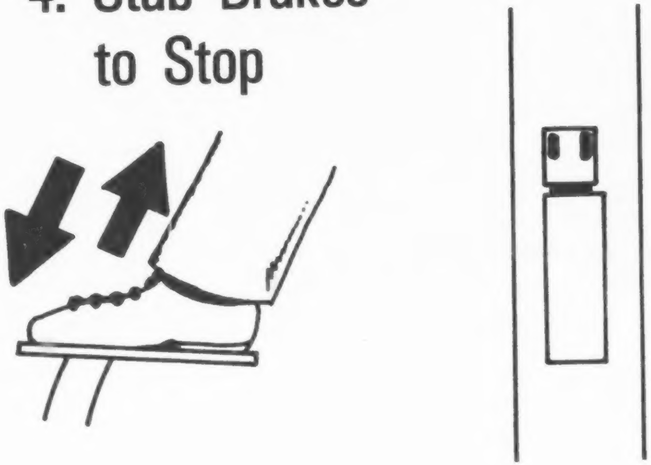
2. Corrective Steering



3. Countersteer

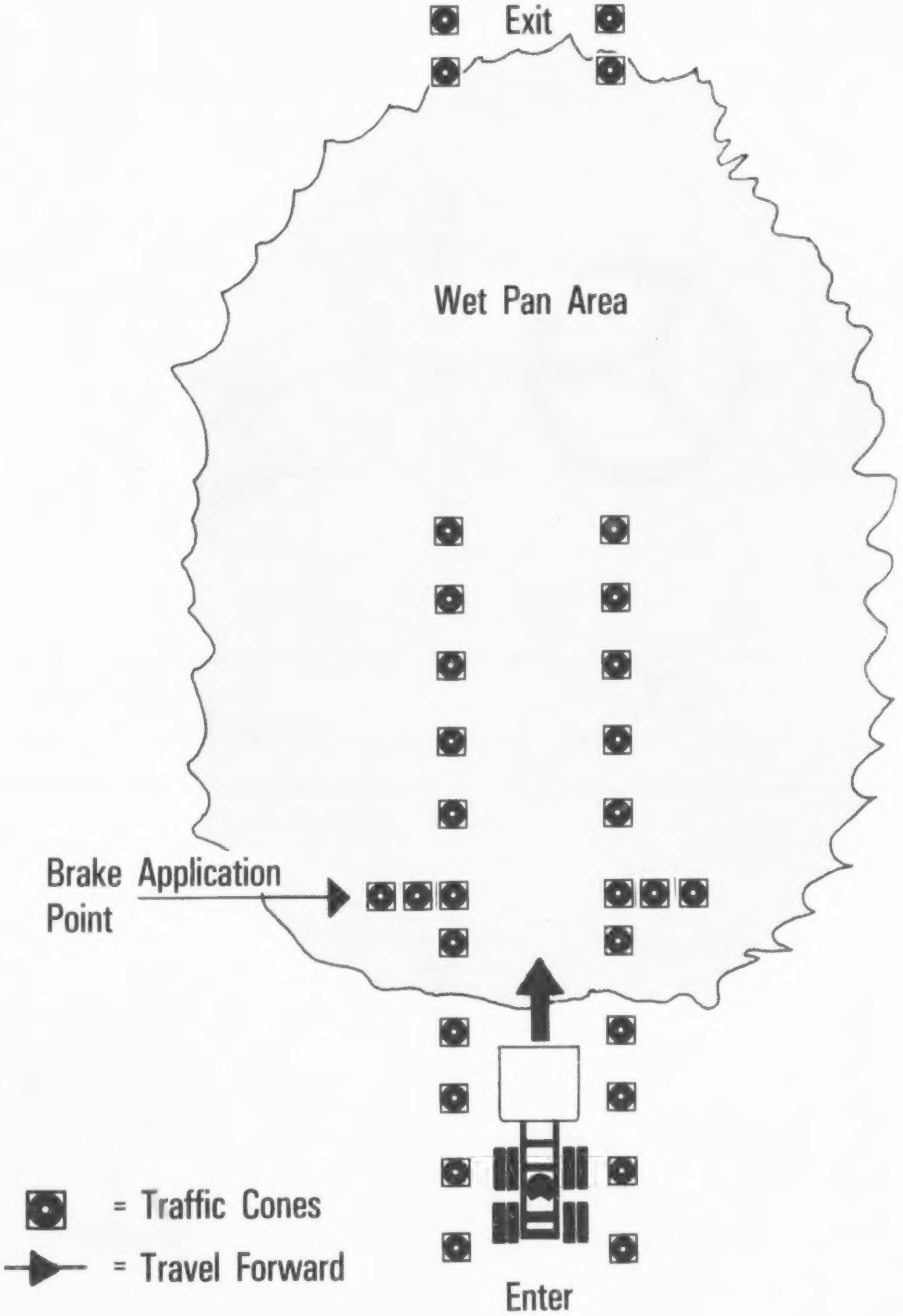


4. Stab Brakes to Stop



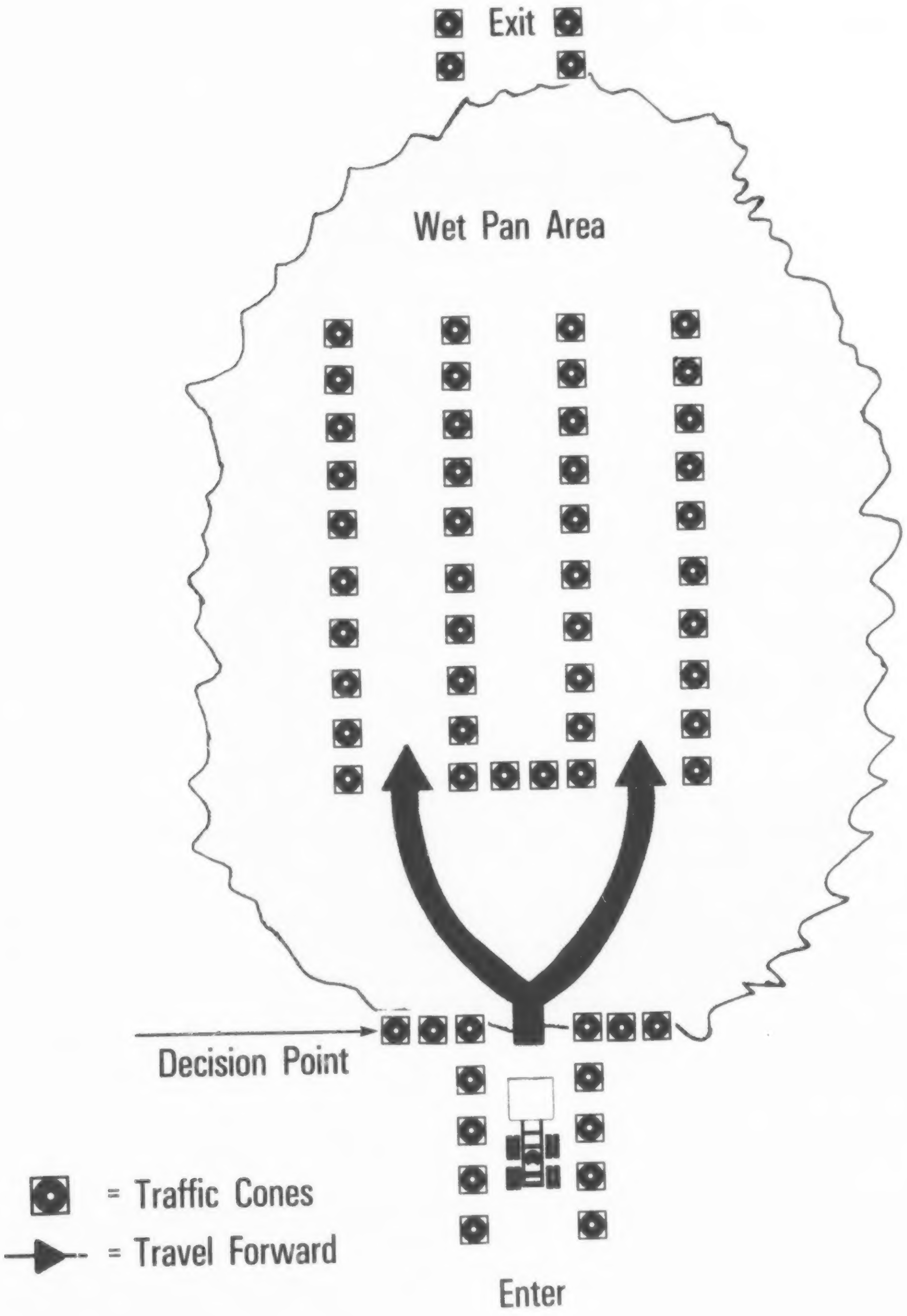
Visual 9

Controlled Braking Exercise


Exit
Wet Pan Area
Brake Application Point
Enter
= Traffic Cones
= Travel Forward

Visual 10

Turn and Controlled Braking Exercise


Exit
Wet Pan Area
Decision Point
= Traffic Cones
= Travel Forward
Enter

LESSON 2 SKID CONTROL AND RECOVERY EXERCISES (RANGE)

Overview

Time Allotted: 7 hours 45 minutes

Prerequisites: Unit 3.3, Lesson 1

Purpose:

The purpose of this lesson is to help students develop skill in responding automatically to skids in a way that will enable them to recover quickly and minimize the chances of a serious accident. The instructor will supervise all lesson activities from inside the cab of the tractor while the student is driving on the skid pan.

Materials

Instructional Aids

None

Student Material

Special range safety rules for skid control and recovery
Range safety rules from Unit 1.1

Instructor Material

Range diagrams for exercises 1-3

Equipment

Instructor should review carefully the requirements for vehicles to be used in skid pan training contained in the "Equipment and Materials" section of the Administrator's Manual.

A tractor and trailer equipped with an antijackknife device that does not interfere with instruction by requiring student responses that are not part of the required skid recovery procedure. Specifically, antijackknife devices that are only actuated when the vehicle's brakes are fully applied are inappropriate since they do not permit controlled or "stab" braking. For further information on appropriate antijackknife devices, consult the Administrator's Manual.

An empty trailer with a low center of gravity (e.g., flatbed).

A white cross should be on all painted wheels to aid student drivers and observers to see which wheels are locked up and when lockup occurs.

An independent braking system that allows selective application of front wheel, drive wheel, and trailer wheel brakes is desirable, but not mandatory. If available, it will permit instructors to create front wheel, drive wheel, trailer wheel, and all wheel skids and to enable students to experience each and to gain practice in recovery from each.

Cones to delineate exercise maneuvers (approximately 30).

Facilities

A skid pan that meets the following requirements:

- a wetted surface area of at least 100 feet in diameter. (preferably larger)
- a sealed surface with a low coefficient of friction.
- a source of water that can be used to wet the skid pan area continuously.
- drainage to carry runoff to sewers or other means of disposal.
- a dry area at least 75 feet wide surrounding the wetted surface.
- an access path to the skid pan that will allow acceleration of speeds of 20 - 30 mph.

(Skid pan requirements are described in the "Equipment and Materials" section of the Administrator's Manual.)

bContent

Activity or Topic	Approximate Time
1. REVIEW OF RANGE SAFETY RULES AND DEMONSTRATION RUN BY THE INSTRUCTOR	15 minutes
2. TRACTOR SKID EXERCISE	90 minutes
3. TRACTOR STOP EXERCISE	90 minutes
4. TRACTOR TURN AND STOP EXERCISE	90 minutes
5. TRACTOR-TRAILER STOP EXERCISE	90 minutes
6. TRACTOR-TRAILER TURN AND STOP EXERCISE	90 minutes
	7 hours 45 minutes

1. REVIEW OF RANGE SAFETY RULES AND DEMONSTRATION RUN BY THE INSTRUCTOR (15 minutes)

Instructor will review the following:

Don't enter maneuver area until clear
- Student may not be able to control direction of vehicle
- Other vehicles won't be able to maneuver very well either

When in doubt of ability to stop
- Keep brakes fully applied
- Dry pavement beyond skid pan will stop vehicle

Only driver and instructor in cab
- Driver needs plenty of room in cab
- Observers can see what's happening better from outside

Observers stay where assigned by instructor
- Must remain upstream of entry to skid pan
- Rig may slide sideways due to slope of skid pan (for drainage)

2. TRACTOR SKID EXERCISE (1 hour 30 minutes)

Purpose

The purpose of this exercise is to develop student ability in the recognition and recovery of tractor skids.

Range Layout

The skid pan must be free of any obstacles, only two markers that represent the entry point of the pan should be used. The vehicle will be operated with no semi-trailer.

Directions

1. This exercise will last a total of 90 minutes, each student is to receive a minimum of 30 minutes behind the wheel in tractor skid practice, in two 15 minute segments.
2. Each 15 minute session with a student will consist of the following exercise runs:
   a. Uncontrolled Skid--The purpose of this exercise is to allow students to experience a completely uncontrolled skid. It will be performed as follows:
      (1) The students will enter the skid pad at 15 mph.
      (2) On command of the instructor, the student will apply the brakes fully and maintain them fully applied till the

vehicle stops. If the vehicle is equipped with an instructor operated brake system, the instructor should lock up the tractor drive wheels rather than have the student apply the brakes.

(3) The student should not attempt to maintain control of the vehicle through corrective steering.

(4) This exercise should be run only once with each student.

b. Controlled Skid--The purpose of this exercise is to allow students to experience the difficulty in maintaining directional control and bringing a vehicle to a stop when the wheels brakes are locked.

(1) Student should enter the skid pad at 10 mph.

(2) At the command of the instructor, the student will apply the brakes as in (a) above.

(3) The student should attempt to maintin directional control by corrective steering and countersteering.

(4) Additional runs should be made until the student is able to maintain additional control, or until the instructor is convinced the student will not be able to do so with the drive wheels locked up.

(5) Students who are successful in maintaining directional control, entry speed should be raised 15, 20, and 25 mph.

(6) Instructor should point out to the students the difficulty in maintaining directional control of the vehicle with the rear wheels locked.

3. Students will rotate from behind the wheel to positions along the edge of the range where observations can be made in a safe manner.

4. Observer students will be provided instruction by an assistant instructor or through radio communication with the instructor in the cab.

Observation

The instructor will observe for failure to use the following procedure for maintaining directional control properly.

Corrective steering
    Steer in the direction the vehicle is to go

Need to overcorrect; turn more quickly and further than on dry surface

Countersteering
- As vehicle resumes correct course, must correct early to avoid "Overshoot"
  - Occurs when countersteer initiated too late
  - Vehicle continues to turn in the opposite direction

Countersteer again, if necessary
- Continued countersteering produces "fishtailing"
- Each correct should get smaller until vehicle assumes straight course

Instructor should watch for the following common problems:
- Not turning the wheel quickly enough to arrest skid.
- Not being ready for countersteering quickly enough to prevent overshoot.
- Giving up--not sticking with the countersteering long enough.

Evaluation

Student performance will be evaluated in terms of the student's ability to maintain a straight path with the wheels locked.

3. TRACTOR STOP EXERCISE (1 hour 30 minutes)

Purpose

The purpose of this exercise is to develop student ability to bring the tractor to a controlled stop while operating on a slippery surface.

Range Layout

See Range Diagram, "Controlled Braking"

Directions

1. This exercise will last a total of 90 minutes, each student will receive a minimum of 30 minutes behind the wheel in practicing controlled stops in the tractor, in two 15 minute segments.
2. Each 15 minute session with a student will consist of the following runs:
   a. Enter the skid pad at 15 mph, on command of the instructor, apply the brake (use techniques described in Unit 3.2) and come to a stop.
   b. Braking Point apply the brakes using the "stab" braking technique described in Unit 3.2 till the vehicle comes to a complete stop.
   c. Use corrective and countersteering to maintain directional control.
   d. Repeat a - c with speeds of 20 and 25 mph until the session is complete.

3. Students will rotate from behind the wheel to positions on the range where observations can be made safely.

4. Instructor will ride in the tractor cab to supervise the practice runs. After each run the instructor will discuss the student's performance, giving directions for improving the tractor stopping.

5. Students will rotate from behind the wheel to positions along the edge of the range where observations can be made in a safe manner.

6. Observer students will be provided instruction by an assistant instructor or through radio communication with the instructor in the cab.

Observation

The instructor will observe for failure to perform the proper procedure for controlled stopping on a slippery surface.

Apply brake fully
Release brake when wheel stops rolling
    Observe wheels in mirror, until learned "by feel"
    Releasing avoids skid
    Reapply brake when wheel starts to roll

Repeat "stab braking" sequence until vehicle slow sufficiently
In each stab, allow time for brake system to recover
    Wheels must start to roll again
    Reapplying too quickly can result in skid
    Generally takes about 1/2 to 1 second for brakes to recover

The instructor will watch for the following common problems
    Failure to release brakes long enough to restore friction

NOTE: In bobtail operation, if surface is extremely slippery and wheel bearings are cold, wheels may not rool freely.

Not braking long enough (light "taps" instead of "stabs")
Preoccupation with braking resulting in loss of directional control

Evaluation

Student performance will be evaluated against the following criteria:
    Does not strike cones
    Stopping distance

4. TRACTOR TURN AND STOP EXERCISE (1 hour 30 minutes)

Purpose

The purpose of this exercise is to develop student ability to turn and stop the tractor when operating under slippery conditions.

Range Layout

A lane change area must be marked with traffic cones. See diagram "Turn and Controlled Braking."

Directions

1. This exercise will last a total of 90 minutes, each student will receive a minimum of 30 minutes behind the wheel practice in turning and stopping the vehicle under slippery conditions, in two 15 minute segments.

2. Each 15 minute session with a student will consist of the following:

   a. Enter skid pan at 10 mph.

   b. At the Decision Point the instructor will direct the student to turn right or left.

   c. On receiving the direction command from the instructor, the student will apply the brakes once (i.e., one "stab") for initiating the lane change.

   d. After releasing the brake, the student will perform a quick lane change, in the direction indicated by the instructor, prior to reaching the obstacle.

   e. After completing the lane change, the student will use "stab" braking techniques to bring the vehicle to a stop.

   f. While bringing the vehicle to a stop, the student will make necessary steering adjustments to maintain directional control.

   g. Student will repeat a - f at 15, 20, and 25 mph until the practice session is completed.

3. Each student will rotate from behind-the-wheel to observation posts on the range.

4. Observer students will be provided instruction by an assistant instructor or through radio communication with the instructor in the cab.

Observation

The instructor will observe for failure to use the following procedure properly:

Tractor turn
- Turn quickly
  - Use hand-over-hand technique
  - Each turn approximately 180°

- Avoid braking in turn
  - Brake once before beginning turn
  - Avoid braking while steering

Tractor Stopping
- Apply brake fully
- Release brake particularly when tires squeal
- Repeat "stab braking" sequence until vehicle slows sufficiently
- Allow time for brake system to recover

Instructor should watch for the following common problems

- Not braking enough before turning (e.g., a perfunctory stab)
- Braking while turning
- Oversteering during turn
- Pumping the brakes too fast only wastes air pressure and never allowing the wheels to unlock
- Pumping the brakes too slow and not stopping quickly enough

Evaluation

Student performance will be evaluated against following criteria:
- Turning in correct direction
- Number of cones struck
- Stopping distance

5. TRACTOR-TRAILER STOP EXERCISE (1 hour 30 minutes)

This exercise routine can only be performed if the required antijackknife device is installed on the vehicle to be used. If not, the lesson would be terminated at this point.

Purpose

The purpose of this exercise is to develop student ability to bring the tractor-trailer to a controlled stop while operating under slippery conditions.

Range Layout

Same as Tractor Stop Exercise of this lesson.

Directions

1. This exercise will last a total of 90 minutes; each student will receive a minimum of two 15 minute segments behind the wheel in practicing controlled stops of the tractor-trailer.

2. Each student will rotate from behind-the-wheel to positions on the range where observations can be made safely.

3. Instructor will ride in the tractor cab to supervise the practice runs.

4. During each 15 minute session, the student will perform the following:

   a. Enter the braking area on the skid pan at 10 mph.

   b. Upon reaching the braking point, apply the brakes using the "stab" braking technique.

   c. Maintain proper direction using countersteering.

   d. Come to a complete stop, keeping the tractor and trailer in line.

5. The instructor will point out any instance in which the trailer starts to jackknife (as observable in the rearview mirror or in the sound of the antijackknife device), explaining to the student what the situation is and what could have occurred if the vehicle were not rigged with an antijackknife device.

6. Repeat (4) and (5) until the student performs correctly. Then repeat the activity at speeds of 15, 20, and 25 mph.

7. Instruct the students to do the following:

   Students who are observing from the range will

      Observe the action of tractor and trailer as it is being stopped.

      Watch the jackknife and determine what type it was (tractor vs. trailer). Why driver did or did not regain control of rig.

   Student behind-the-wheel will

      Position vehicle at the start point after completion of each run.

      Follow directions given by the instructor for each exercise run.

      Note whether rig jackknifed.

   Each student will rotate from behind-the-wheel to positions on the range where observations can be made safely.

   Observer students will be provided instruction by an assistant instructor or through radio communication with the instructor in the cab.

Observation

The instructor will instruct students to employ the same procedures as used in the tractor stop. However, the student will also be told:

- The vehicle response to be different because of the trailer.
- The tractor and trailer may jackknife producing some unexpected sounds and vehicle response.
- The antijackknife equipment will prevent damage.

instructor should watch for the same common problems as previously discussed for the Tractor Stop.

Evaluation

Student performance will be evaluated against the following criteria:

Turning in the right direction
Number of cones struck
Stopping distance

6. TRACTOR-TRAILER TURN AND STOP EXERCISE (1 hour 30 minutes)

Purpose

The purpose of this exercise is to develop student ability to turn the tractor-trailer and come to a complete stop on a slippery surface.

Range Layout

Same as Tractor, Turn and Stop exercise of this lesson

Directions

1. This exercise will last a total of 90 minutes, each student will receive two 15 minute segments behind-the-wheel in practicing a turn and stop maneuver.
2. Each 15 minute session with a student will consist of the following runs:
   a. The student will enter the exercise area at 15 mph
   b. As the vehicle reaches Decision Point, the instructor will ask the student to turn right or left.
   c. Upon getting the direction command, the student will brake once to reduce speed.
   d. After releasing the brake, the student will perform a lane change in the direction indicated by the instructor.
   e. Upon completing the lane change, the student will brake to a stop using the "stab" braking technique.
   f. The exercise will be repeated until the student is able to make a successful lane change and bring the rig to a controlled stop.
   g. Upon successfully completing the exercise at 15 mph, the student will repeat the exercise at 15, 20, 25 mph.
3. Each student will rotate from behind-the-wheel to positions on the range where observations can be made safely.

4. Observer students will be provided instruction by an assistant instructor or through radio communication with the instructor in the cab.

Observation

The instructor will observe for failure to perform the maneuver in the same manner as Tractor Turn/Stop, again warning them of the effect of the trailer upon handling and of possible jackknifing.

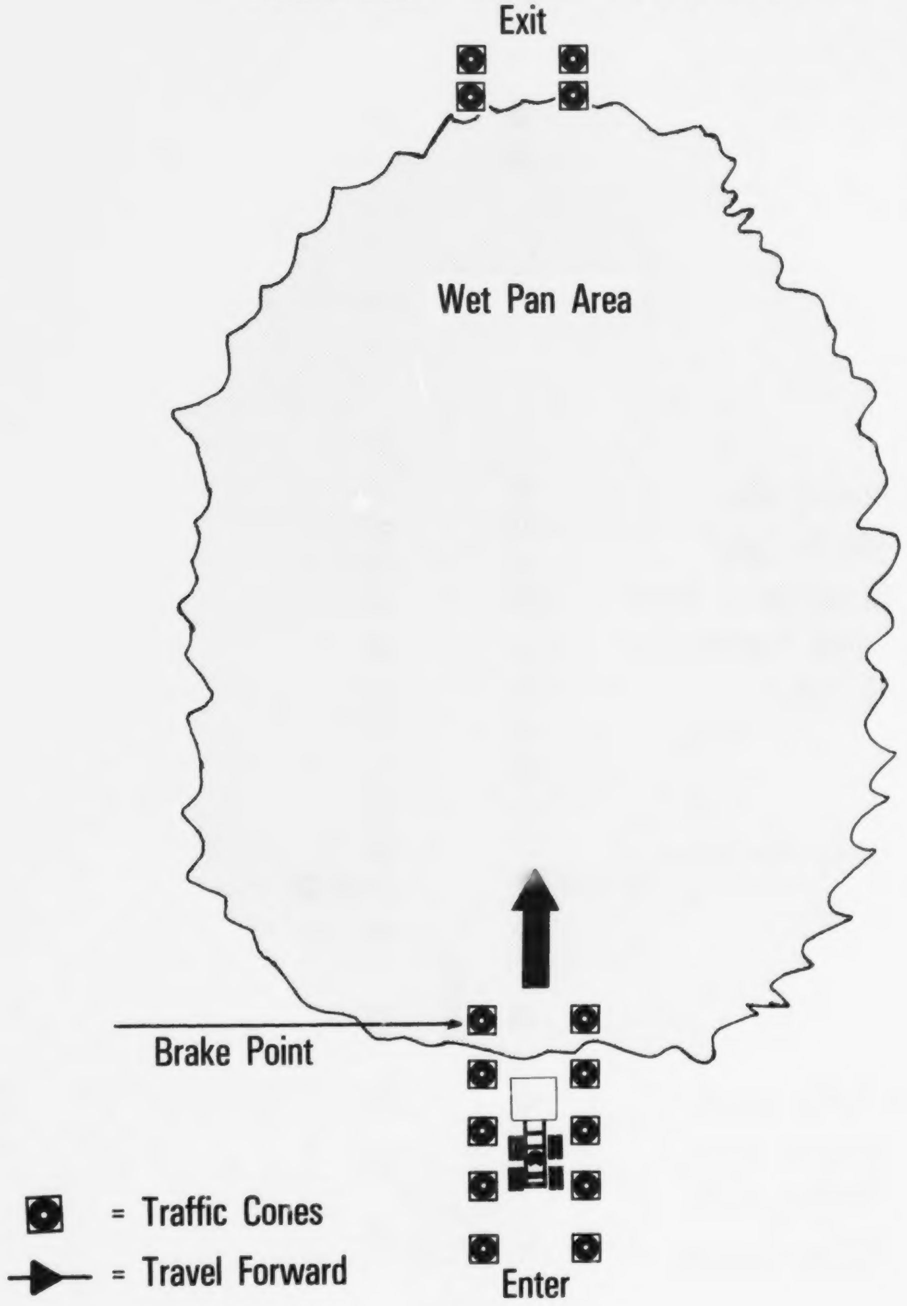
Instructor should watch for the same common problems as previously discussed for Tractor Turn/Stop.

Evaluation

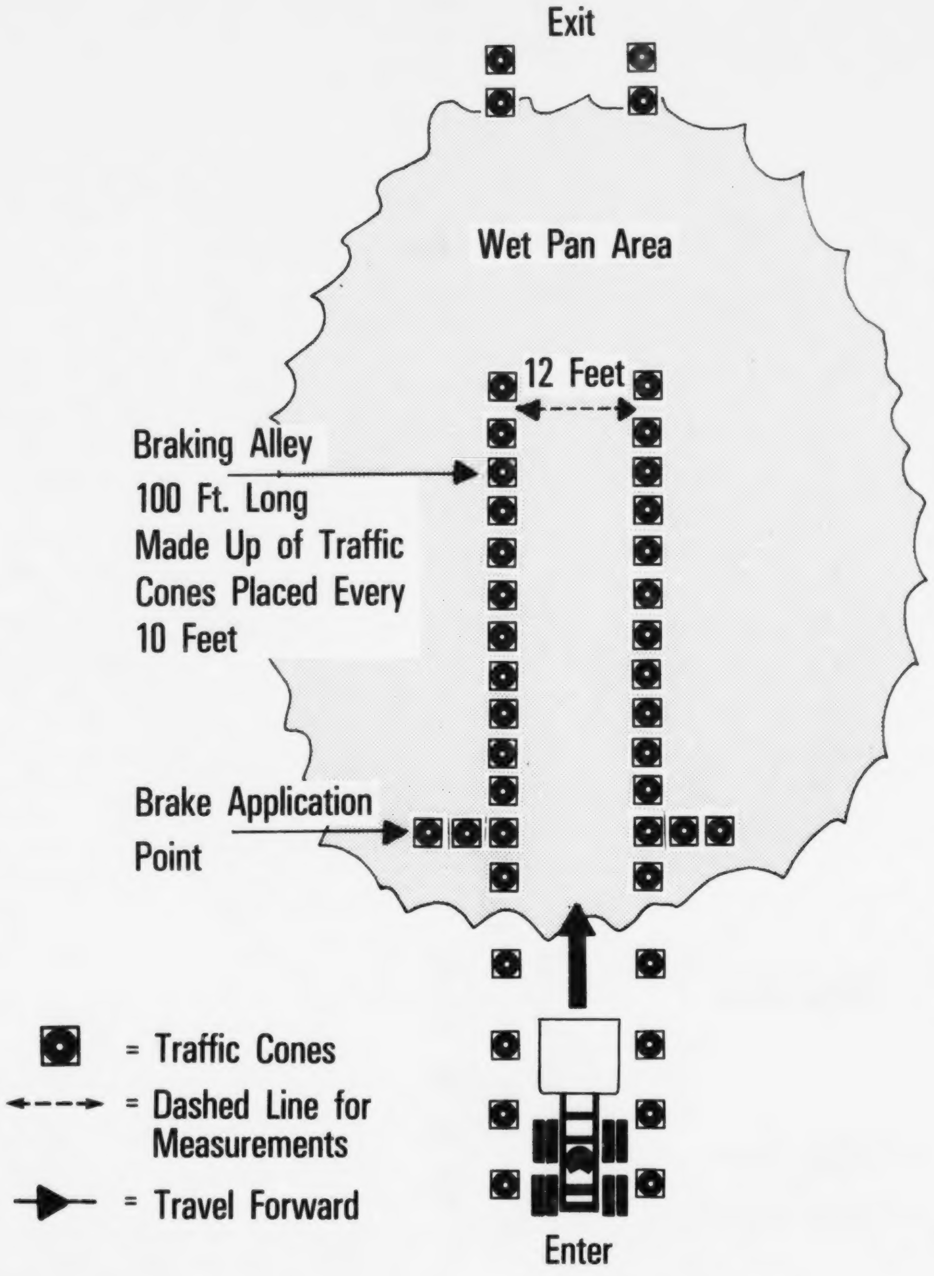
The student performance will be evaluated against the following criteria:

Turning in the right direction
Number of cones struck
Stopping distance

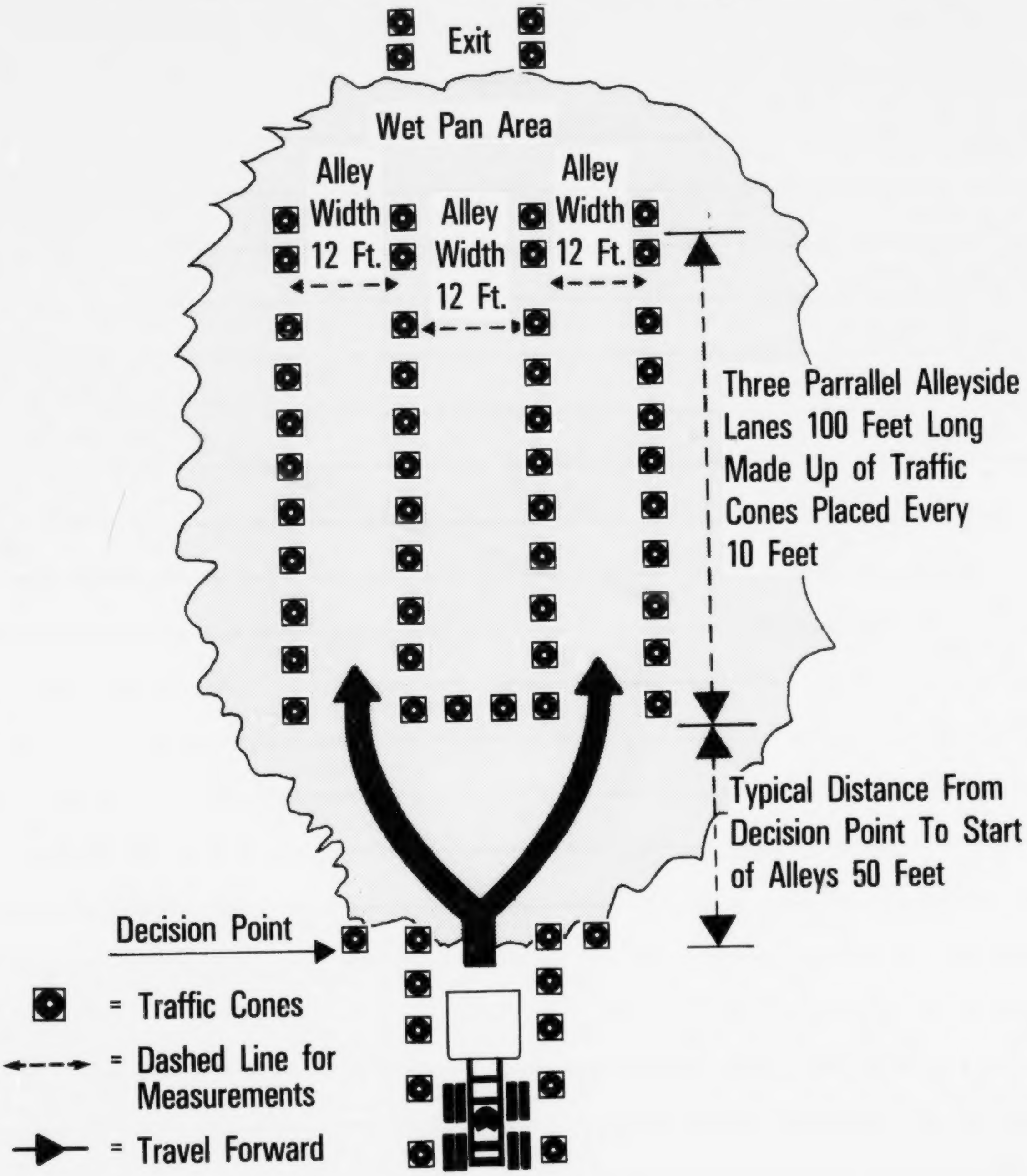
Range Diagram – 1
Tractor Skid Exercise


Exit
Wet Pan Area
Brake Point
Enter
= Traffic Cones
= Travel Forward

Range Diagram – 2
Controlled Braking Exercise


Exit
Wet Pan Area
12 Feet
Braking Alley
100 Ft. Long
Made Up of Traffic
Cones Placed Every
10 Feet
Brake Application
Point
Enter
■ = Traffic Cones
←---→ = Dashed Line for Measurements
—▶— = Travel Forward

Range Diagram – 3
Turn and Controlled Braking Exercise


Exit
Wet Pan Area
Alley Width 12 Ft.
Alley Width 12 Ft.
Alley Width 12 Ft.
Three Parrallel Alleyside Lanes 100 Feet Long Made Up of Traffic Cones Placed Every 10 Feet
Typical Distance From Decision Point To Start of Alleys 50 Feet
Decision Point
= Traffic Cones
= Dashed Line for Measurements
= Travel Forward

Notes:

SECTION 4
VEHICLE MAINTENANCE

SECTION 4
VEHICLE MAINTENANCE

This section is intended to provide students with sufficient knowledge of the tractor-trailer and its systems and subsystems to insure that they gain sufficient knowledge and respect of their role in vehicle inspection, operation, and vehicle maintenance and its impact upon the safety and efficiency with which their vehicle operates. It is also designed to teach drivers elementary vehicle servicing and/or maintenance tasks for which many drivers are responsible (depending upon employer's individual policies). It must be emphasized that it is **NOT** the goal of this section to make mechanics out of the students, rather the emphasis is to enable students to better interact with mechanics by instilling the basic knowledge necessary to do so intelligently.

To achieve these goals, this section contains the following units:

Unit 4.1 - Vehicle Systems--To enable students to understand the operating characteristics and purpose of each vehicle's system, the function of its major components, and symptoms of component failure, and the implications thereof.

Unit 4.2 - Preventive Maintenance and Servicing--To enable students to meet the preventive maintenance and servicing requirements of their vehicles, and perform simple emergency type repairs.

Unit 4.3 - Diagnosing and Reporting Malfunctions--To enable students to diagnose and report vehicle malfunctions and proper emergency starting procedures.

Notes:

UNIT 4.1
VEHICLE SYSTEMS

UNIT 4.1 VEHICLE SYSTEMS

PURPOSE

The purpose of this unit is to identify major systems to both tractors and trailers and the components thereof. The goal is to teach students the operational theory and purpose of each system, function of major components thereof and its impact upon both safety and economy of operation. Students must have a thorough grounding in this area in order to understand when a vehicle system or component thereof is functioning properly, is in imminent danger of failing, and when it has failed.

OBJECTIVES

This unit introduces no new performance, skill or attitude objectives. It is intended primarily to provide knowledge that is required for the remainder of the units in this section.

Knowledge Objectives

Students must know location, function, operation, and common failures of the following vehicle components:

- Frames, Suspension Systems, and Axle Systems
- Engines
- Fuel Systems
- Air Intake and Exhaust Systems
- Lubrication Systems
- Cooling Systems
- Electrical Systems
- Drive Trains
- Brake Systems
- Wheels, Bearings, Rims, and Tires
- Steering Systems
- Coupling Systems

LESSONS

Lesson 1.	**Vehicle Systems (Classroom)**	**11 hours 15 minutes**
Lesson 2.	**Vehicle Systems Demonstration (Lab)**	**2 hours**

LESSON 1 VEHICLE SYSTEMS (CLASSROOM)

Overview

Time Allotted: 11 hours 15 minutes

Prerequisites: Units 1.2, 1.3, 1.4, 1.5 and 1.7

Purpose:

The purpose of this lesson is to enable students to understand the operating characteristics of each vehicle system, the function of each major component, and symptoms of component failure. The lesson starts with the frame and builds the vehicle on up until it is complete, as in an assembly line process.

Materials

Instructional Aids

A total of 208 visuals broken down into 12 vehicle systems.

Student Material

The Student Manual contains an illustrated description of the systems and components of a tractor-trailer entitled "Vehicle Systems" which students should be assigned to read on their own prior to instruction on Section 4.

Instructor Material

Various tractor and trailer manufacturers publish operator's and maintenance manuals. Manuals are also furnished by vehicle component manufacturers, such as brake system manufacturers, and filtration system manufacturers. They, too, publish excellent material on preventive maintenance, care, operation, troubleshooting, etc., of their components. A wide variety of such material and literature should be available to draw upon to answer student questions, provoke discussion, and provide answers to questions that individual students raise.

Equipment

Cutaway parts, models or the actual components are highly desirable to have in the classroom to aid student learning, especially damaged or failed parts from which the instructor can lead a discussion on what sort of error caused the part to become damaged or to fail. It is strongly recommended that an "operational demonstration board" be built or purchased for teaching air brake systems. Such boards contain all of the "operational components" of a tractor-trailer brake system and when furnished with a supply of compressed air, can provide "live" demonstrations of how the system and its components function.

Content

Activity or Topic	Approximate Time
1. FRAME, SUSPENSION SYSTEMS AND AXLE	60 minutes
2. ENGINES	70 minutes
3. FUEL SYSTEMS	35 minutes
4. AIR INTAKE AND EXHAUST SYSTEMS	25 minutes
5. LUBRICATION SYSTEMS	25 minutes
6. COOLING SYSTEMS	30 minutes
7. ELECTRICAL SYSTEMS	90 minutes
8. DRIVE TRAINS	75 minutes
9. BRAKE SYSTEMS	165 minutes
10. WHEELS, BEARINGS, RIMS, AND TIRES	50 minutes
11. STEERING SYSTEMS	20 minutes
12. COUPLING SYSTEMS	30 minutes
	11 hours 15 minutes

1. FRAME, SUSPENSION SYSTEMS AND AXLE SYSTEMS (1 hour)

Introduction

These topics are designed to give students a fundamental knowledge of

- Various types of frames and their components
- Some of the more common types of suspension systems and axles as well as their components
- Effects of improperly maintained or damaged frames, suspension systems and axles on safety and economy of operation which create excessive
  - Vehicle handling and control problems
  - Road shock to vehicle systems and cargo
  - Fuel consumption and tire wear

Frames

Visual 1.1 Example of Truck Frame

Purpose

- Serve as a skeleton or foundation of any tractor or trailer
- Support, carry, connect and keep all vehicle systems and components in alignment
- Carry cargo body
- Provide support point for raising vehicle to gain access to underside for maintenance or repairs

Types of Frames

Material

Most frames are made of steel or aluminum

Steel--Generally falls into three categories:
  - Low carbon steel--supports up to 36,000 pounds per square inch (PSI)
  - High tensile steel--50,000 PSI
  - Heat treated steel--110,000 PSI
  - PSI is a measurement of frame strength, it is the maximum load that can be applied without permanent bending of the frame

Aluminum--Generally used in large highway tractors--falls into two categories:
  - Extruded, heat treated alloy--35,000 PSI
  - High strength alloy--60,000 PSI

Visual 1.2 Frame Stresses

Stresses on Frames
  - Materials must be capable of handling stresses
  - Vertical bending as weight of cargo pushes downward
  - Torsion, as vehicle turns corners
  - Axial and lateral bending as one wheel or one side of vehicle rises and dips due to bumps, curb, etc.

Material must be flexible enough to bend and then spring back (return) to original shape

Construction

There are three basic types of frame construction:

- Straight
- Drop
- Monocoque

Visual 1.3 Straight Frame

Straight Frame
- Found in both tractors and trailers
- Frame does not drop or rise but stays straight throughout its length

Visual 1.4 Drop Frame

Drop Frame
- Use
  - Found in both tractors and trailers
  - More commonly found in trailers
  - Two kinds
    - Single drop--drops once behind king pin
    - Double drop--drops between king pin and trailer axles
- Advantages: Provides lower body height
  - Has lower center of gravity
  - Easier to load from ground
  - Can carry extremely high pieces of cargo within maximum height limit of 13 feet 6 inches
- Disadvantages
  - More expensive to construct

Visual 1.5 Monocoque

Monocoque (Frameless Trailers)
- Construction
  - Roof, sides and floor of trailer are an integral unit
  - Body and chassis are one and the same
- Use
  - Used in trailers hauling bulk items with very little weight (e.g., snack foods, such as potato chips)
  - Damage to roof, sidewalls or floor greatly impair structural integrity of whole vehicle

Components and Functions

Three basic frame components

- Frame rails
- Crossmembers
- Gussets

Frame Rails

A vehicle's frame starts out with two rails running parallel to each other
Frame rails can be straight, single drop or double drop
They can also be

Visual 1.6 Extra Thick Rails

Extra thick--high-stress areas

Visual 1.7 Types of Frame Reinforcement

Reinforced--high-stress areas

Visual 1.8 Double Frame

Double framed (one frame within another)--used for vehicles operated in severe service

Visual 1.9 Cross Members and Gussets

Cross Members and Gussets .

Smaller pieces of frame rail material used to connect the two main rails

Function
- Lend support to frame
- Strengthen frame rails

Visual 1.10 Other Frame Components

Other Frame Components

Engine Mounts--Mounting brackets used to bolt engine to frame

Suspension Hangers--Pieces that attach suspension to frame rails

Body Supports--Brackets that attach truck body to frame

Fuel Tank Supports--Connects fuel tank to frame

Tow Hooks--Hooks attached to frame allowing vehicle to be towed

Visual 1.11 Coupling Devices

Fifth Wheel Mounting Plates

Trailer lift ramp--attached to frame ends to allow tractor to get under the nose of a low trailer

Locating and Recognizing Problems

Importance--Locating and recognizing problems is necessary for

- Accident Prevention--Frame failure at road speeds can result in loss of control and/or cause a serious accident

- Vehicle Handling--Misaligned, bent, or sagging frame makes handling difficult in: normal driving
  - skid prevention and recovery

- Fuel Consumption--Defective frames can cause:
  - Misalignment of wheels
  - Engine to work harder to turn wheels

Normal Pretrip Inspection

- Pretrip inspection should include inspection of tractor and trailer frames for signs of
  - Twisting
  - Sagging
  - Bending
  - Cracking
  - Breaking

- Particular attention must be paid to high-stress areas
  - Fifth wheel attachment points
  - Cab mounting points
  - Engine mounting points
  - Spring hanger attachment points
    - Frame dip points on single or double drop frames
- Look for any post-production vehicle modifications that could weaken the frame:
  - Holes drilled or cut with a torch
  - Non-factory welding
  - U-bolts applied to the frame without wood "filler box" between the flanges of the frame
- Avoid operating a vehicle under any condition in which
  - A stationary part of the vehicle system may be in contact with a moving part
  - Any portion of the frame could separate or collapse

Recap

- Frame is foundation of vehicle
- Every vehicle component is directly or indirectly mounted on it or suspended from it
- When checking frames if you spot what could be a problem or potential problem:
  - Get expert advice
  - Check operator's manual
- Remember, when a frame breaks, results are nearly always a disastrous accident

Suspension Systems

Visual 1.12 Suspension Systems

Suspension systems connect axles, wheels and tires to tractor or trailer frames

They must
- Support weight of vehicle and its payload
- Cushion rest of vehicle from road shock
- Transmit full braking and steering effort to chassis

Types of Systems and Their Components

An infinite variety of suspension systems are used in manufacturing various types of tractors and trailers.

The same type of suspension system may be used on all axles of a tractor or a trailer.

One type may be used on a steering axle and yet another type used on a driven axle or a trailing axle.

Factors considered in the design of suspension systems

- Driver comfort
- Terrain to be traveled
- Speed at which vehicle will generally travel
- Anticipated weight of cargo
- How fragile the cargo is
- Initial cost of suspension system

Capacity of Suspension System

Vehicle should never be loaded beyond rated capacity of suspension system

- For normal highway use, capacity of springs on each axle should be 1,000 lbs. more than actual axle weight
- When traveling off highway, rated capacity should be 1,500 lbs. more than normal axle weight

Three of the more common types will be discussed

Visual 1.13 Leaf Springs

Leaf Spring Suspension

Most common type of system composed of
- Series of narrow metal strips of various lengths
- Bolted together in stacks
- Attached at their center by U-bolts
- Attached to frame at each end by frame hangers

Leaf springs may be
- Overslung--Spring passes over top of axle
- Underslung--Spring passes beneath axle

Two primary types of construction

Visual 1.14 Stack Leaf

- Stack Leaf
  - Several strips of steel
  - Stacked on top of each other
  - Used in heavy-duty systems, primarily on rear axles

Visual 1.15 Tapered Leaf

- Tapered Leaf
  - One or two strips of steel
  - Used on light-weight tandem axle vehicles (onhighway) or on heavy-duty front-axle suspension systems

Visual 1.16 Auxiliary Springs and Torque Rods

- Many leaf spring systems use
  - Helper or Auxiliary Springs
    - Usually needed on single rear axle vehicles
    - Increases carrying capacity
    - Comes into action when load on axle reaches 75 percent of total rear axle load capacity
  - Torque Rods
    - Used in combination with main and auxiliary leaf springs
    - Transmits torque and braking effort to front
    - Helps maintain proper axle alignment

Visual 1.17 Air Suspension

Air Suspension Systems

- Main components
  - Bellows (air bags)
    - Attached to frame and axles
    - Hold compressed air
    - Supports vehicle weight
    - Absorbs road shock
  - Control Arms
    - Keep bellows in position when
      - Turning corners
      - On high-banked roads
      - Negotiating banked turns or curves
  - Air Suspension Ride
    - Gives soft ride to both empty and loaded vehicles
    - Regulates air pressure to
      - Suit load and road conditions
      - Adjust frame height
    - Provides lightweight system
    - Good damage reduction capabilities
  - Disadvantages
    - Bellows easily damaged
    - Must be constantly inspected
    - Stability can be problem if one side fails

Visual 1.18 Torsion Bar Suspension

Torsion Bar Suspension

- Composed of heat treated alloy steel rods
  - Rectangular or circular shaped
  - Located on each side of axle
- Provides torsional (twisting) reaction to
  - Cushion shock
  - Support load
- Operation
  - Weight of vehicle
    - Twists torsion bar
    - Holds it in twisted position
  - As wheels pass over bumps
    - Bar twists move as wheels rise
    - Twists back as wheels drop
  - Twisting of torsion bar absorbs shock
- Advantages
  - Is relatively light weight
  - Evenly distributes load and shock stress to frame rails
  - Each bar acts independently of each other
- Disadvantages
  - Can be hard riding
  - May not respond as well as other systems in negotiating turns

Visual 1.19 Shock Absorbers

Shock Absorbers

- A component common to most suspension systems used in conjunction with
  - Leaf spring
  - Air suspension
  - Torsion bar
- Shock absorbers play a key role in vehicle handling
- By controlling up and down motion, shock absorbers
  - Dampen road shock (repeated up and down motion) up to 960 times per minute
  - Cushion suspension system rebound
  - Prevent wheel hop
  - Prevent side sway of vehicle
- Two basic types of shock absorbers
  - Air
    - Works with compressed air to retard motion
    - In some cases, compressed gas is used

  - Hydraulic (two types)

    - Telescopic
      - Has a narrow tube-shaped chamber
      - Contains fluid
      - Up and down motion of vehicle forces fluid through small passes in the chamber
      - Resistance of fluid to flow through small opening creates forces that damp out the up and down movement of the vehicle

Rotary
- Short, wide cylindrical container
- Works on same principle as telescopic shock absorbers
- Up and down motion is changed to rotary motion
    - In visual, as arm goes up and down, shaft revolves
    - As shaft revolves, fluid passes from one chamber into another
    - Resistance of fluid resists rotation of shaft
- Advantages are
    - Fluid can be added, it can be overhauled and can be externally adjusted

Suspension must be matched with load carried over each axle
- Weight will vary from front to back
- Improperly rated suspensions will cause dangerous vehicle control problems

Type of system used depends on many factors
- Terrain traveled
- Road conditions
- Operating speeds
- Type of cargo
- Cargo weight

Locating and Recognizing Problems

Identify type of suspension system(s) on vehicle driven

Be sure to understand
- Function of its components
    - Check manual
    - Get advice
- Whether system is functioning properly or not

Closely examine all parts of system as part of your pretrip inspection
Carefully check:

Axle Positioning Parts

Any cracked, broken, loose or missing torque arms, U-bolts, spring hangers likely to permit axle to move from its correct position
- Don't operate vehicle until the malfunction is corrected

Visual 1.20 Damaged Spring Assembly

Spring Assembly

Any leaf spring assembly broken or missing
One or more leaves shifted from normal position, permitting contact with:
- Tires
- Rims
- Brake drum
- Frame

Don't operate vehicle until problem corrected

Air Suspension

Any signs of damage or leaks to air suspension bellows

Torsion Bar Assembly or Torque Arm

- Any part of torsion bar or torque arm that is
  - Cracked
  - Broken
  - Missing
- Any condition that permits body or frame to come in contact with wheels or tires
- Don't operate vehicle until problem corrected

Shock Absorbers

- Any dent or bending likely to cause
  - Binding
  - Loose or missing mounts and mounting bolts
  - Fluid leaks
- Any shock absorber that isn't warm after it has been in use probably has failed
  - Shocks change motion into heat
  - Functioning shock absorbers will be considerably warmer than nearby chassis parts
- Don't operate vehicle until problem corrected

Recap

- Remember
  - A properly functioning suspension system is absolutely critical for safe vehicle handling
  - A defective system will
    - Cause excessive fuel and tire consumption
    - Damage cargo
    - Provide an uncomfortable ride
- When checking suspensions
  - If problem or potential problem spotted, do not operate vehicle until:
    - Operator's manual has been consulted
    - Expert advice or assistance has been obtained in doubtful cases
- Never risk operating a vehicle with a defective suspension system

Visual 1.21 Functions of Tractor-Trailer Axles

Axles

Using the visual, describe the following functions of tractor-trailer axles

- Support weight of vehicle and cargo
  - Transfer weight to wheels
  - Spread weight out over several wheels

- Connect vehicle components to wheels
    - Transfer power
    - Connect brakes
    - Connect steering

Different axles perform different functions

- All axles support weight of vehicle
- In addition
    - Front tractor-trailer axle
        - Connects steering and brakes
        - Provides power on all-wheel drive vehicle
    - Tractor drive axle
        - Transfers power
        - Connects brakes
    - Trailer axle connects brakes
    - Trailer converter gear
        - Supports weight of trailer nose
        - Provides steering for second trailer

Types of Axles

There are many kinds of axles
All kinds fall into two basic types

- Dead
- Live

Dead Axles--a "dead" axle is one that is not powered

Function

- Support vehicle
- Connect steering
- Connect brakes

Visual 1.22 Dead Axle Design

- Design
    - Straight axle--most dead axles
    - Drop center axle--Used to allow space for drive shaft (will be discussed later)

- Construction
    - Solid I-beam
    - Hollow tube or box

Types of Dead Axles

Ordinary Trailer Axle

- Most common use of drive axle
- Connects trailer wheels to trailer body
    - Supports rear of trailer
    - Connects brakes

Steering Axles

- Most steering axles are dead axles
- Allow the wheels to turn in order to steer the vehicle

Visual 1.23 Tractor Steering Axle

Tractor Steering Axle

- Supports and steers front end of tractor
- Front wheel assemblies at each end of the axle turn
- The axle itself does not turn

Visual 1.24 Tandem Steering Axles

Tandem Steering Axles

- Vehicles carrying very heavy loads may require tandem (2) axles to support the vehicle's weight
- Steering assemblies on both axles turn to steer vehicle

Visual 1.25 Single Axle Converter Dolly

Converter Dolly Axle

- Attached to front end of trailer
- Steers the second trailer in a set of doubles
- The entire axle turns to provide steering

Visual 1.26 Self-Steering Semi-Trailer Axles

Self-Steering Semi-Trailer Axles

- At rear end of trailer to be steered
- Reduces offtracking by following path of tractor more closely
- Reduces strain on trailer frame, suspension, and tires
- Improves maneuverability on crooked roads
- Difficult to back; some can be locked in straight ahead position

Visual 1.27 "Michigan Train"

Multiple Axle Assemblies

- Two or more dead axles together
- Purpose
  - Spreads the vehicle and cargo weight over more axles
  - Reduces the weight on any one axle
  - Used primarily because of State weight regulations rather than because of any need to support the vehicle
- "Michigan Train"
  - An example of multiple axle assemblies
  - As many as three axles in one assembly

Visual 1.28 Retractable Axle

Retractable Axles

- Can be raised clear of the pavement
- Reduces wear and tear on tires and axle
- Usually kept in raised position when returning to point of origin with little or no cargo

Visual 1.29 Variable Load Suspension Axles

Variable Load Suspension Axles (VLS)

- Two types:
- One allows adjustment of the amount of weight carried by each axle
  - Air or hydraulic suspension can be adjusted to weight of load
- One equipped with helper springs
  - With no weight on axle, springs lift tires off ground
  - When weight is applied, axle is forced back down on the pavement
- Another way of adjusting axle weight to meet State limits

Visual 1.30 Sliding Tandems on Semi-Trailer

Sliding Tandems on Semi-Trailer

- Allows trailer axle(s) to be moved fore and aft on a track
- Allows transfer of weight back and forth between tractor and trailer
  - Moved forward--more weight on trailer
  - Moved backward--more weight on tractor
  - Locked in place by steel pins
- Adjusts relative weight on tractor and trailer axles
  - Another way of meeting State weight requirements
  - More practical than moving the cargo within the trailer body

Live Axles

- Refers to axles that are powered
  - Function
    - Support vehicle
    - Deliver power to wheels

  - Construction
    - Always hollow in order to accommodate gears and axle shafts to deliver power to wheels
    - Delivery of power to wheels discussed in more detail under "drive trains"

Visual 1.31 Typical Tractor Drive Axle

Single Drive Axle

- Located at the rear of the tractor
- Most tractors have single live axle

Visual 1.32 Powered Front Tractor Steering Axle

Powered Steering Axles

- Like an ordinary front tractor steering axle except that power is delivered to wheels
- Provides additional traction
- Provided on vehicles that will be used where extra traction is required

Visual 1.33 Tandem Axles

Tandem Axles

- "Tandem axles" refers to two axles designed to work in pairs
  - Twin Screw
    - When both axles are powered, tractor is called a "twin screw" or "full tandem"
  - Pusher Tandem
    - Two axles
    - Live rear axle (hence, the term, "pusher")
    - Dead forward axle
      - Must be drop center construciton since it is between drive axle and engine
      - Allows space for drive shaft to connect live axle to transmission
  - Tag Tandem
    - Live axle forward of dead axle
    - Dead axle "tags" along behind live axle
- Purpose of tandem axles
  - Weight distribution
    - Distributes weight over more axles
    - Helps to comply with State weight regulations
  - Additional traction--twin screw tractors

Visual 1.34 Retractable Pusher Tandem

Retractable Pusher Tandem

- Dead axle often retractable (the amount of "drop" at center allows the axle to be raised
- A retractable axle with one tire on each end is called a "peg leg" axle

Visual 1.35 Tri-Drive Axle Assembly

Tri-drive Axles

- Three live axles in the same assembly
- Used where high traction is necessary

Components and Functions

Visual 1.36 Axle Components

Components

Dead Axles

- Design
  - I-beam
  - Tubular
  - Design depends upon vehicle weight and the type of use

- Strength
  - Dual axles capable of supporting up to 25,000 pounds per axle
  - Design strength is based upon
    - State weight limits
    - Intended use
- Flexibility
  - Dual axles designed with certain amount of flexibility
  - Needed to prevent damage from potholes, curbs, etc.

Live Axles

- Must accommodate gears and axle shafts
  - Will be discussed in more detail under "drive trains"

Other Components

- Pads for attaching axle to suspension system
- Brackets for attaching brake system components
- Spindles at each end for connecting:
  - Wheels
  - Wheel bearings

Locating and Recognizing Problems

Inspection

During vehicle inspections, driver should check carefully for any

- Bent, broken, or missing axle alignment parts such as:
  - U-bolts
  - Torque arms
  - Center bolts
  - Spring hangers
- Irregular tire tread wear indicating axle misalignment
- Signs of body or frame rubbing against axle
- Sliding axles (if vehicle so equipped)
  - Be sure all locking pins are in proper position and fully engaged
  - Make sure safety clips holding pins are in place and secured to prevent pins falling out
- Removable, retractable, or VLS axles (if so equipped)
  - Check operators manual
  - Get expert advice
  - Do not operate vehicle with questionable condition until it has been checked out by qualifed service personnel

Operation

While Driving

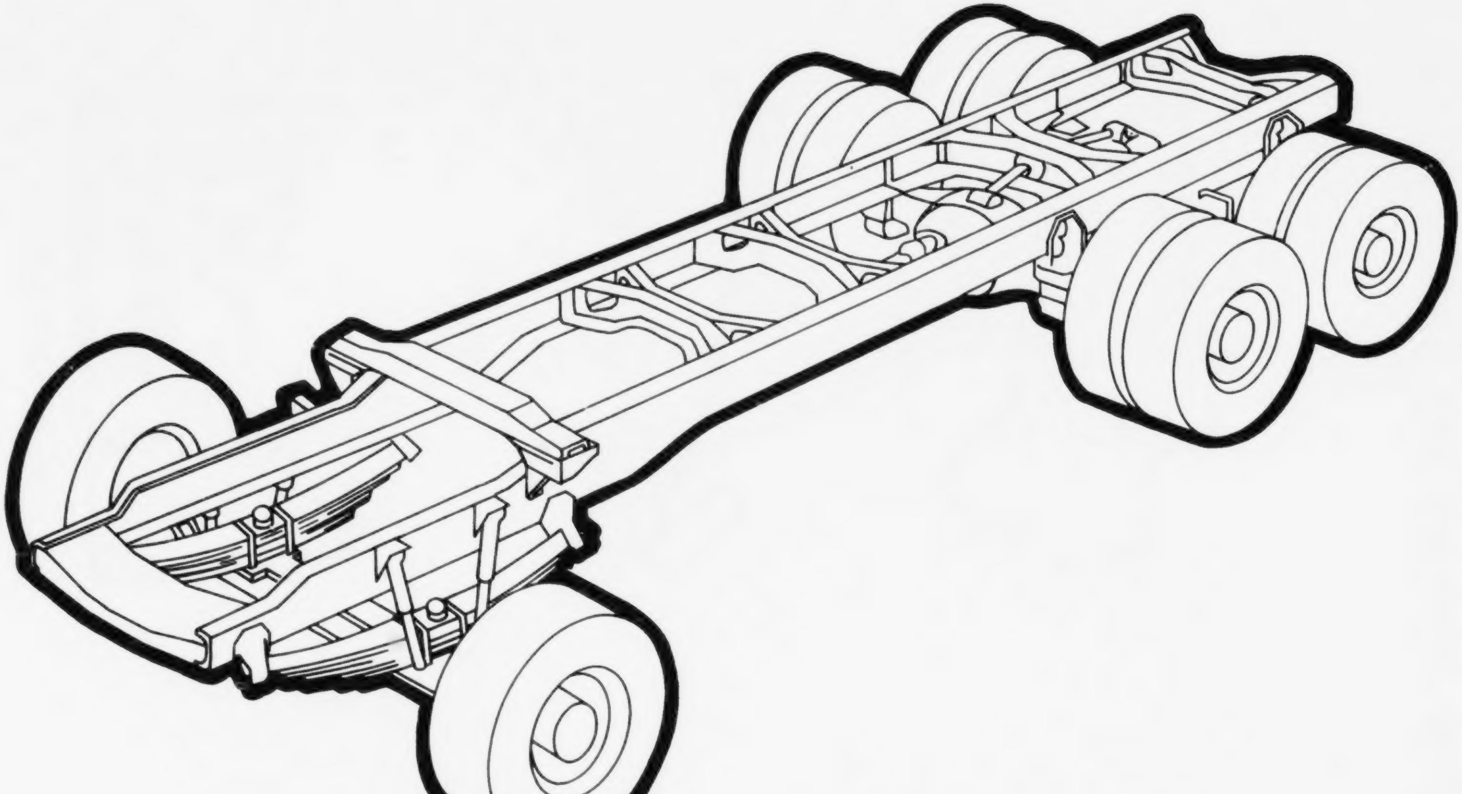
- Look for signs of offtracking "crabbing" motion
- Use mirrors to observe motion of trailer

Recap

It is essential for both safety and economy of operation that drivers know:

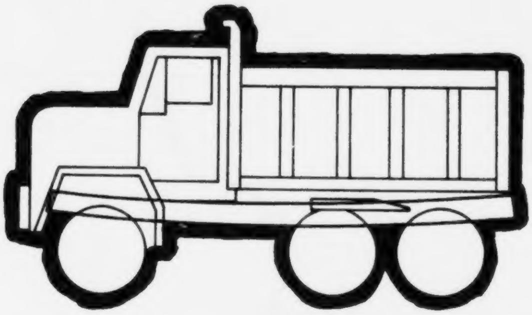
- How to inspect for axle problems
- Consequences of failing to inspect axles
- Rated capacity of axles on their vehicle and how to load it accordingly
- Risks involved in attempting to operate a right with axle problems

Example of Truck Frame

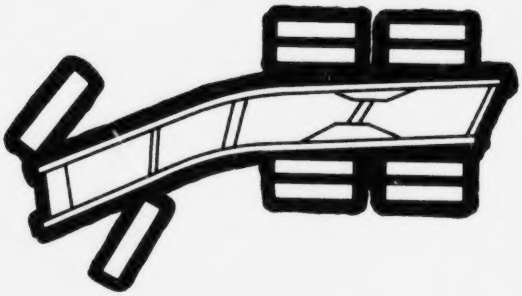


Visual 1.2

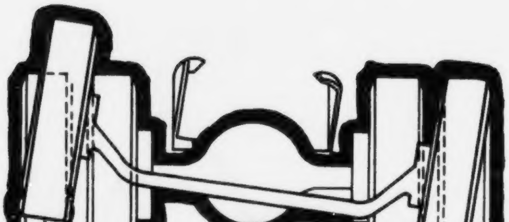
Some Stresses and Strains Placed on Frames



Vertical Bending



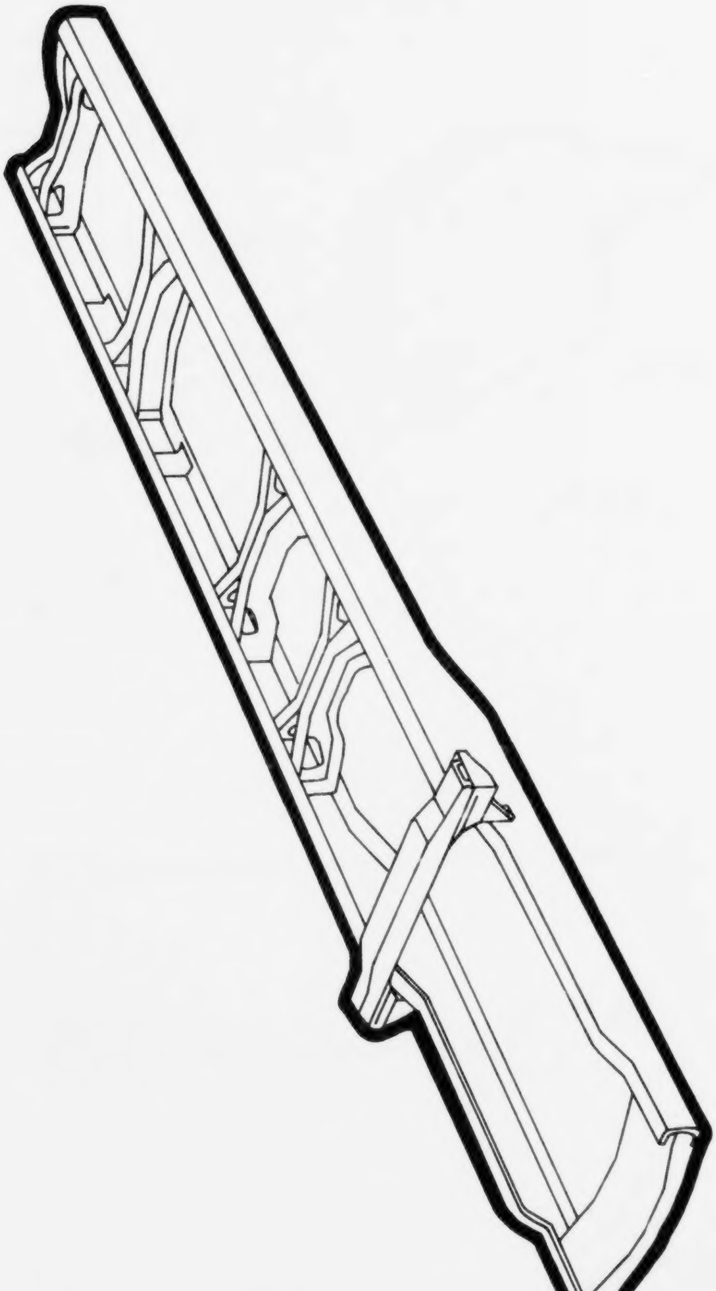
Torsion



Axial and Lateral Bending

Visual 1.3

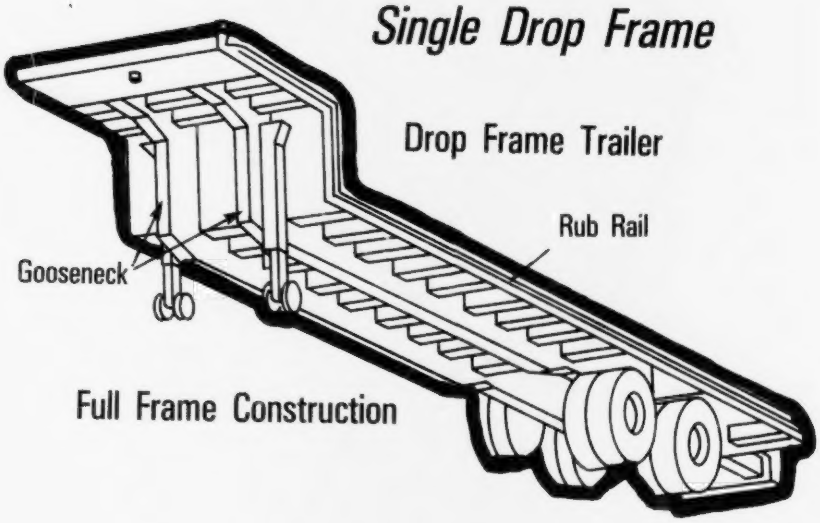
Straight Frame



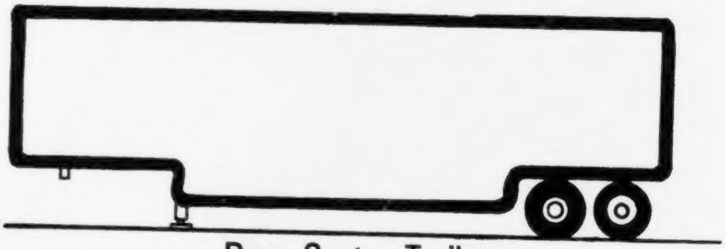
Visual 1.4

Drop Frame

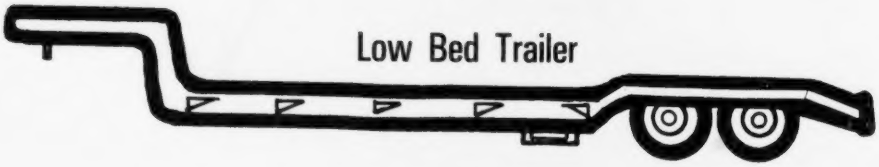
Single Drop Frame


Drop Frame Trailer
Rub Rail
Gooseneck
Full Frame Construction

Double Drop Frames



Drop Center Trailer

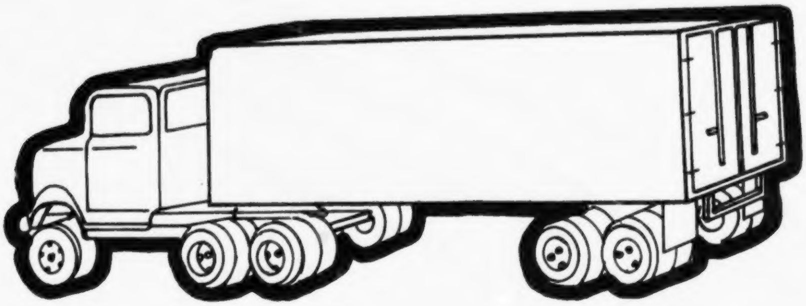


Low Bed Trailer

Visual 1.5

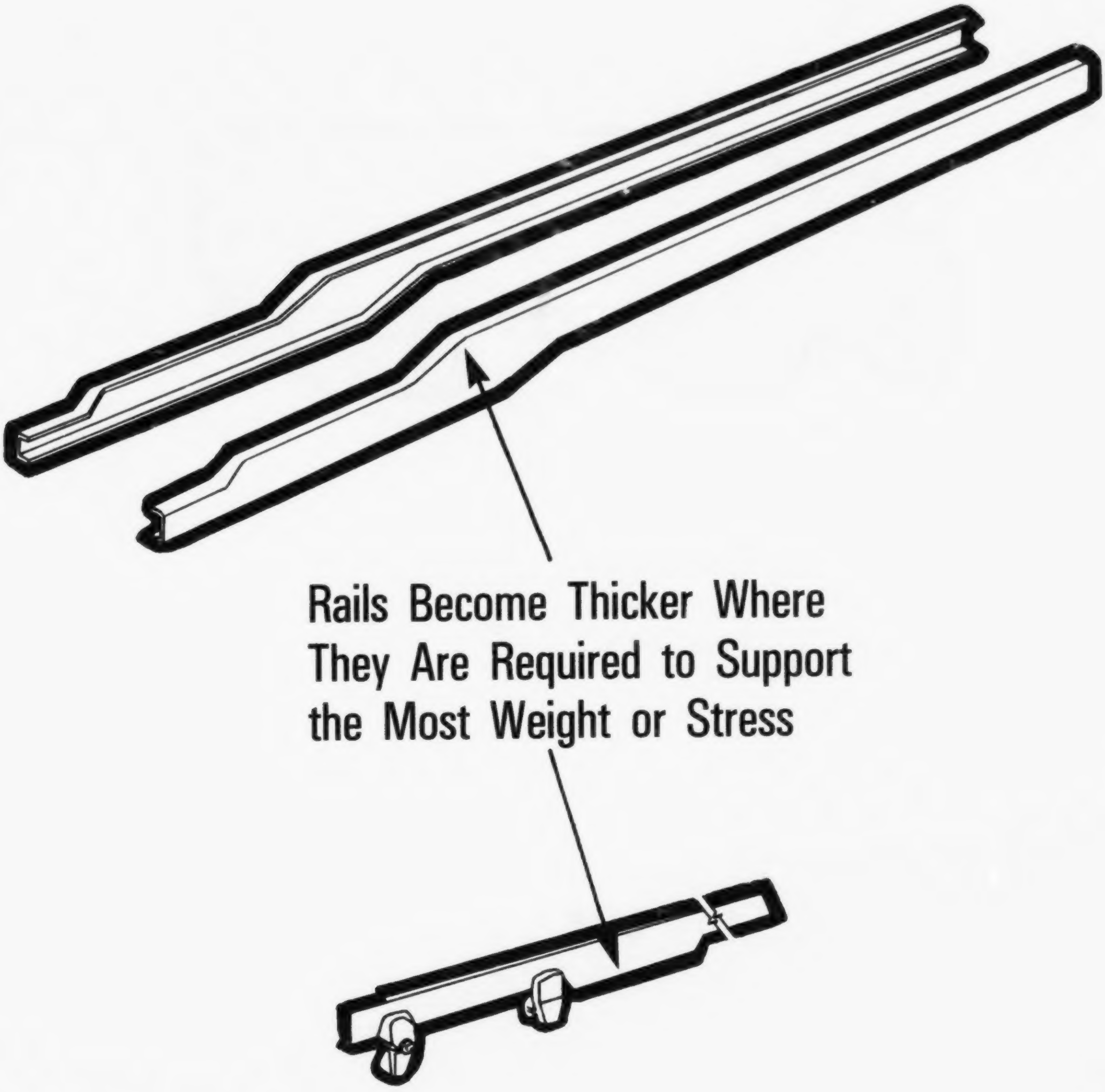
Monocoque

(Frameless Hi-Cube Van Trailer)



Visual 1.6

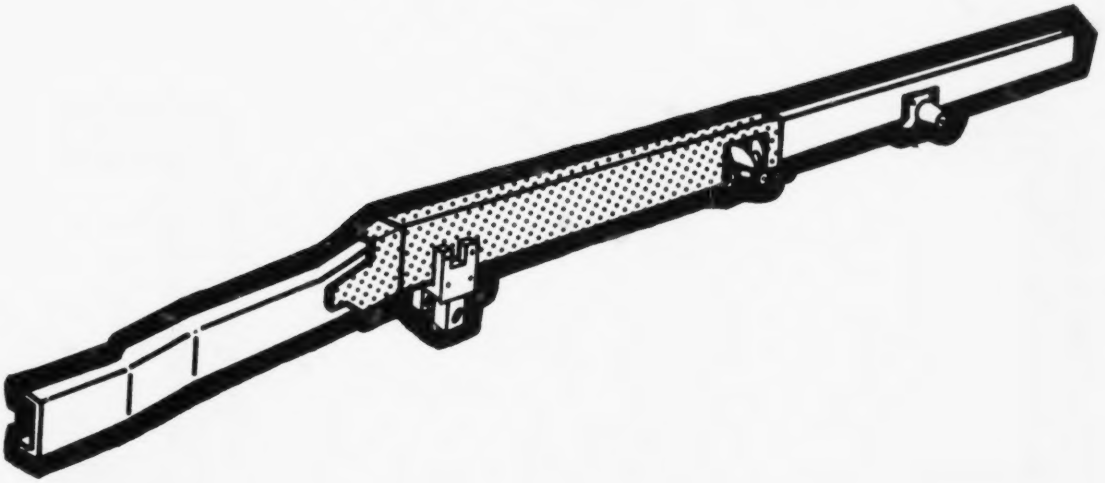
Extra Thick Frame Rails



Rails Become Thicker Where They Are Required to Support the Most Weight or Stress

Visual 1.7

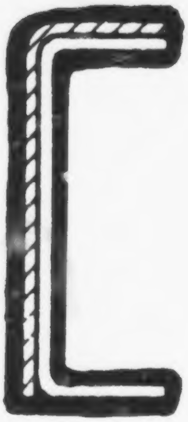
Types of Frame Reinforcement



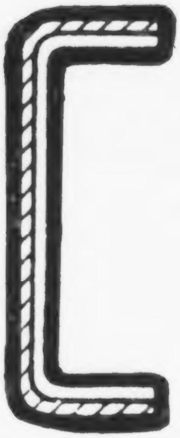
Typical Straight Side Rail With an
Outer Channel Reinforcement

Visual 1.8

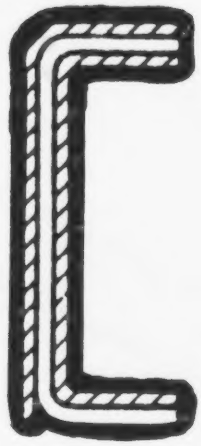
Double Frames



Inverted "L"



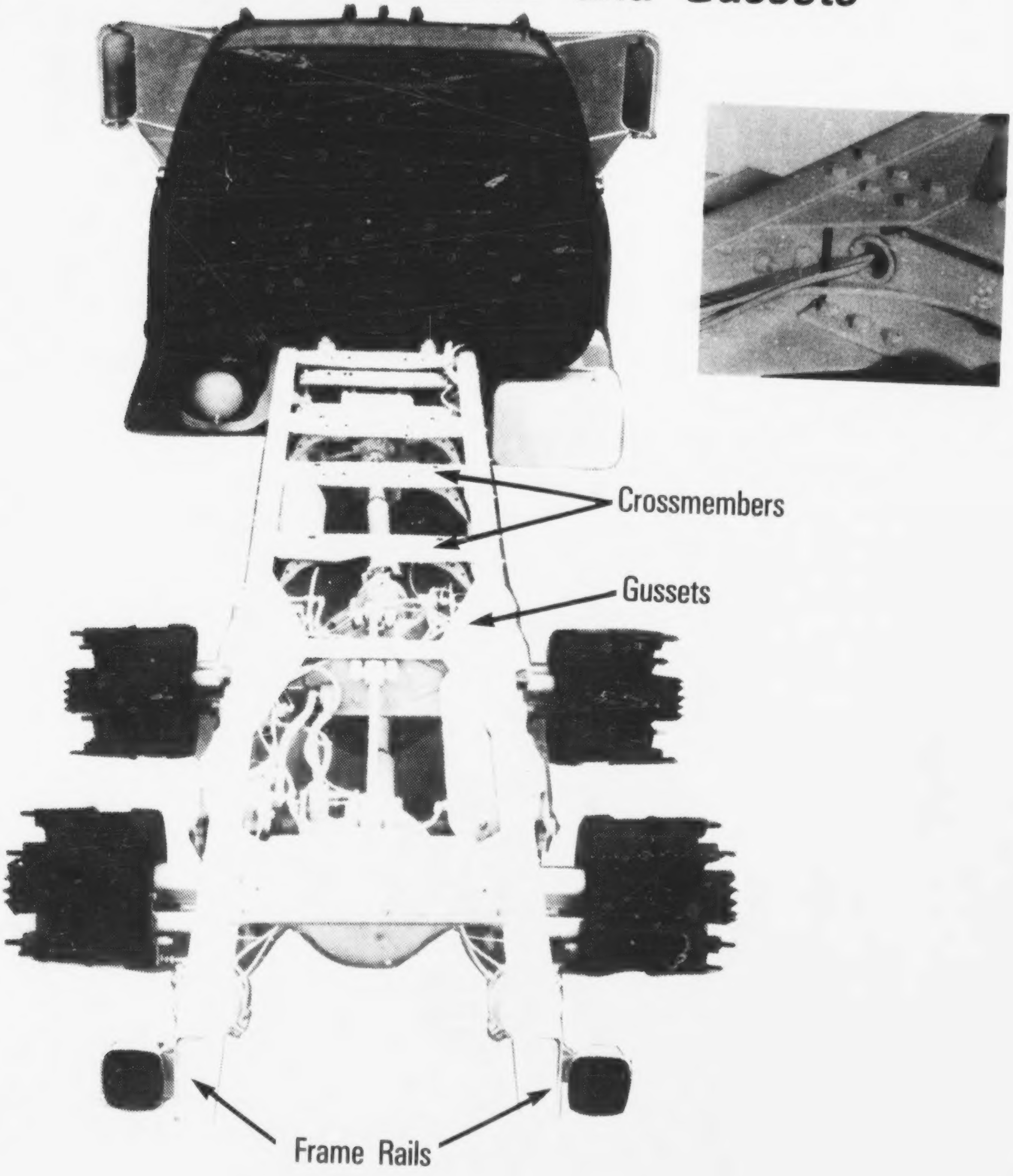
Outer Channel



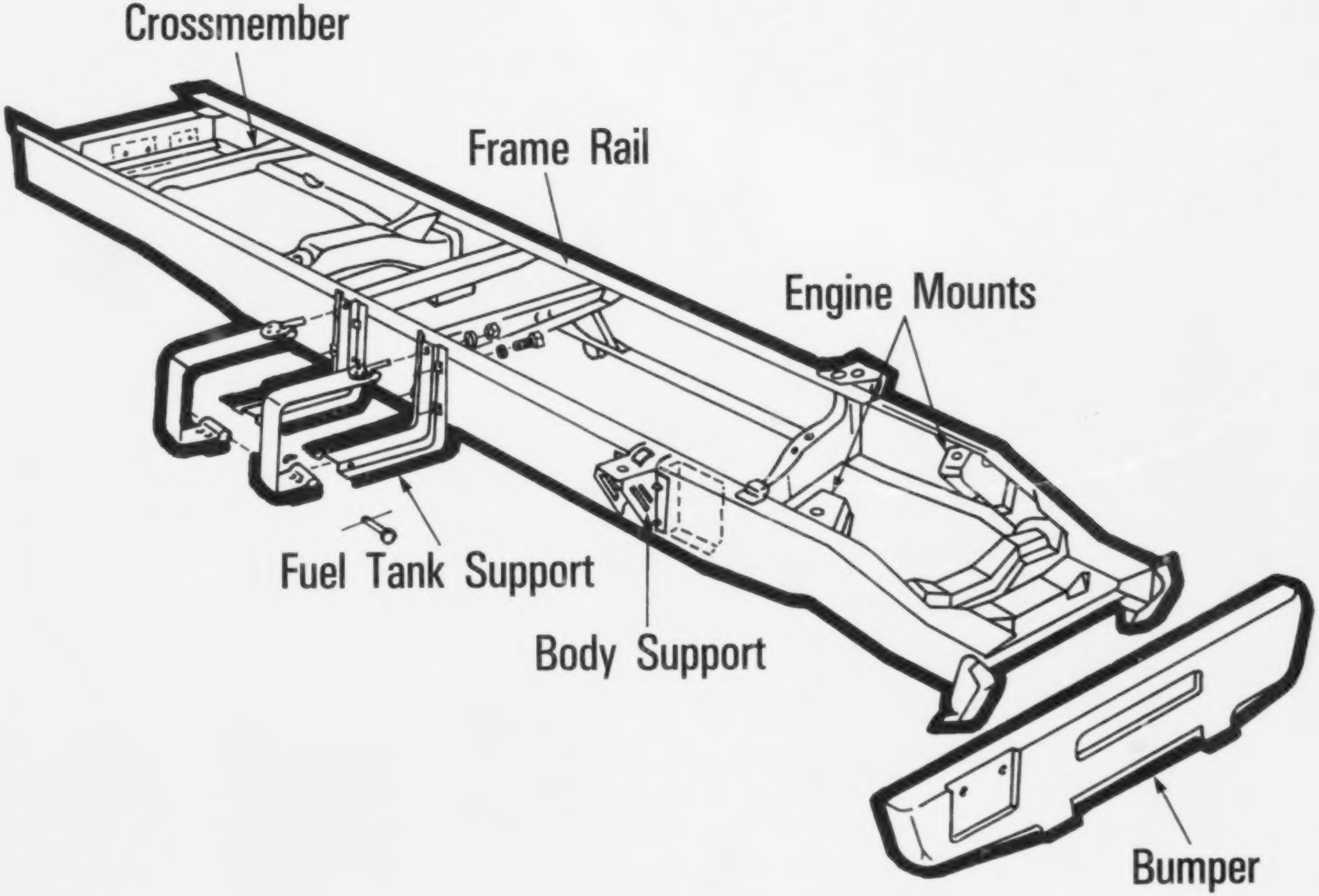
Inner Channel W/"L"

Visual 1.9

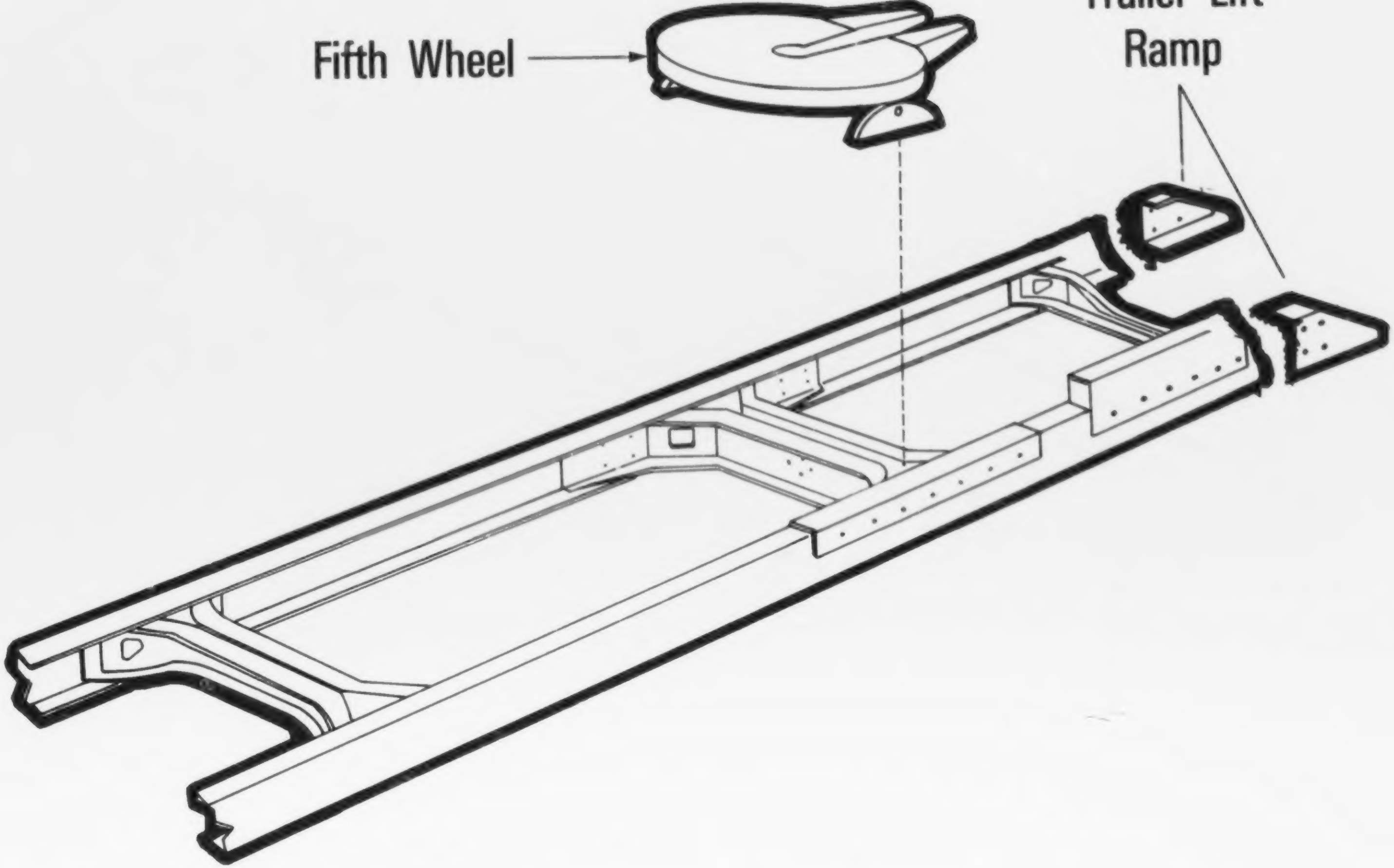
Cross Members and Gussets


Crossmembers
Gussets
Frame Rails

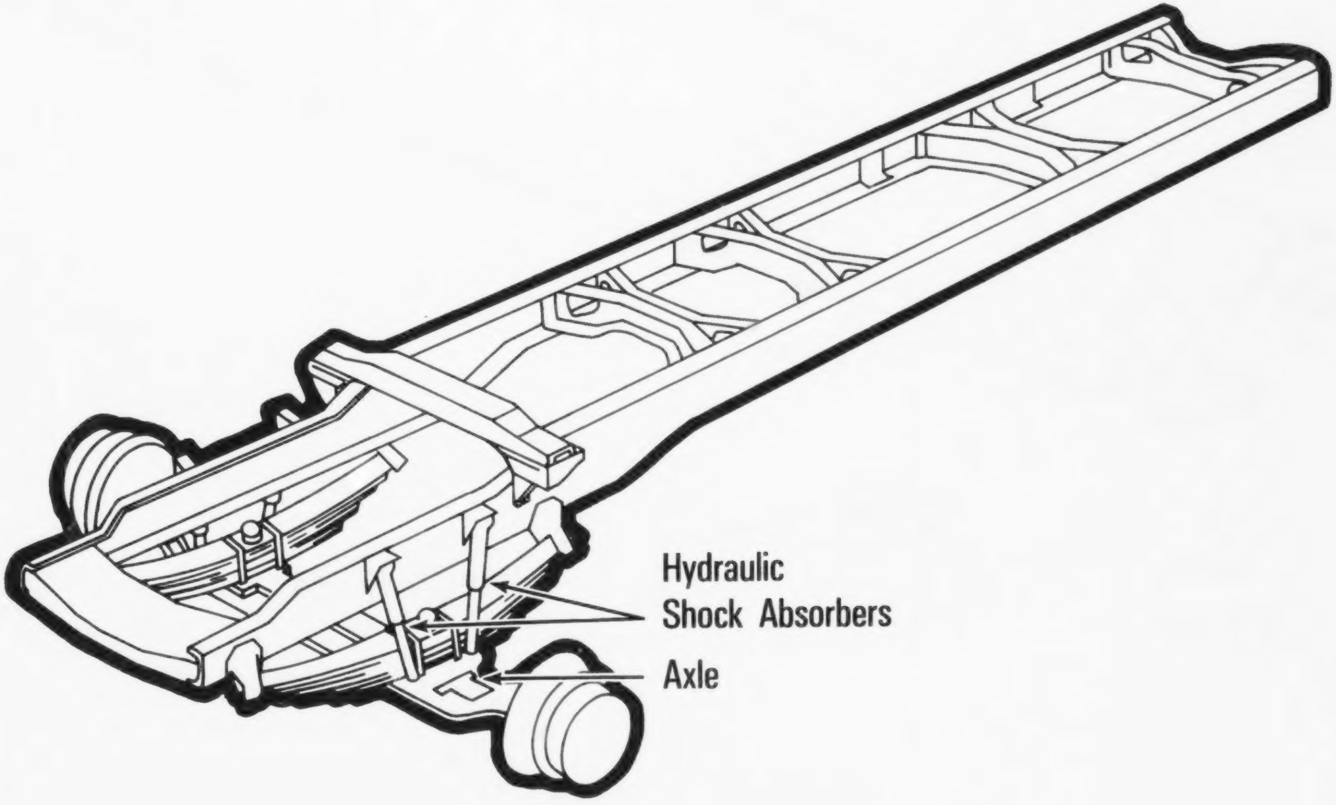
Other Frame Components


Crossmember
Frame Rail
Engine Mounts
Fuel Tank Support
Body Support
Bumper

Coupling Devices


Fifth Wheel
Trailer Lift Ramp

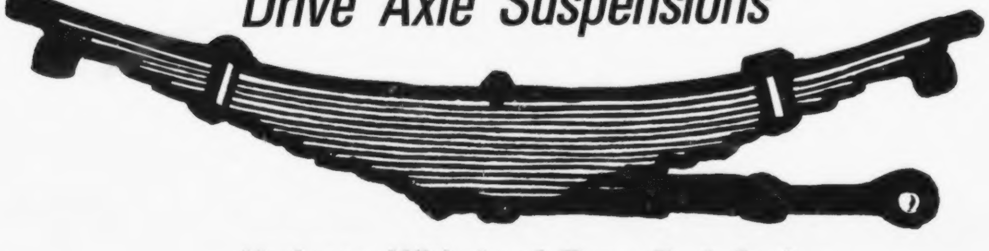
Suspension Systems


Hydraulic
Shock Absorbers
Axle

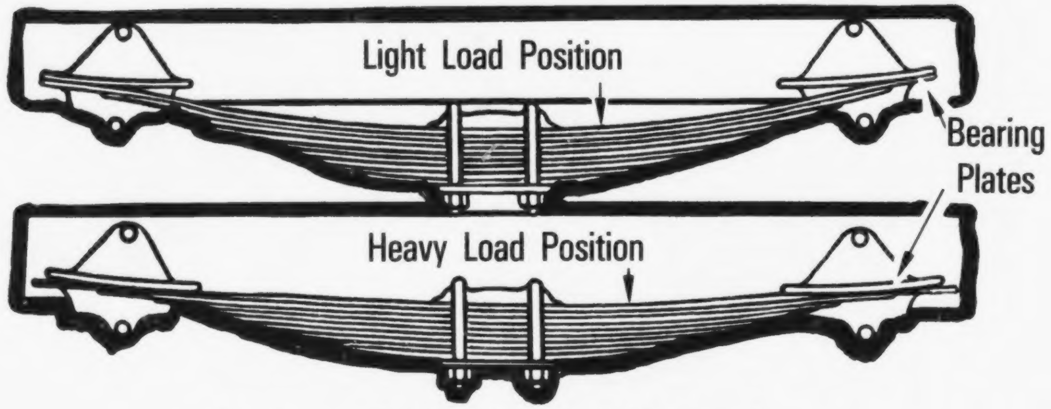
Visual 1.13

Axle Suspensions

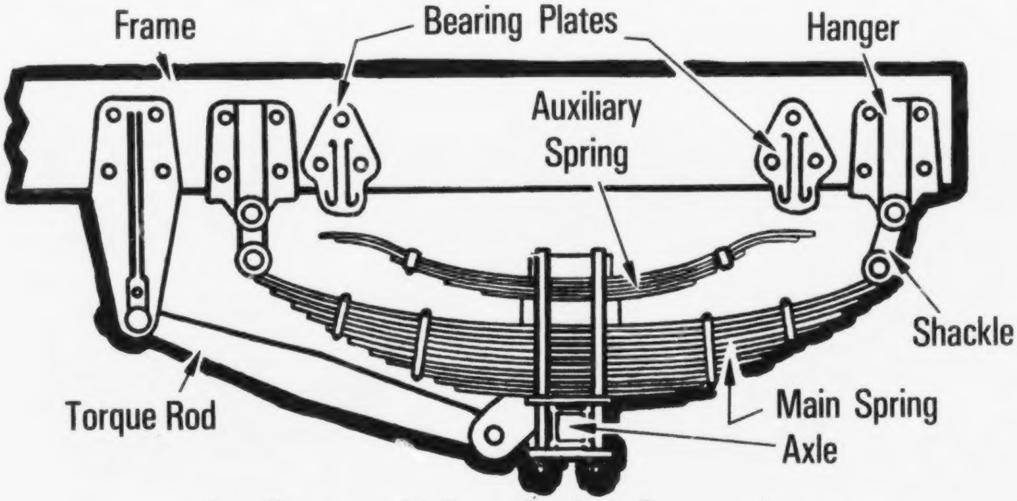
Drive Axle Suspensions



Vari-rate With Leaf Type Rod Spring


Light Load Position
Bearing Plates
Heavy Load Position

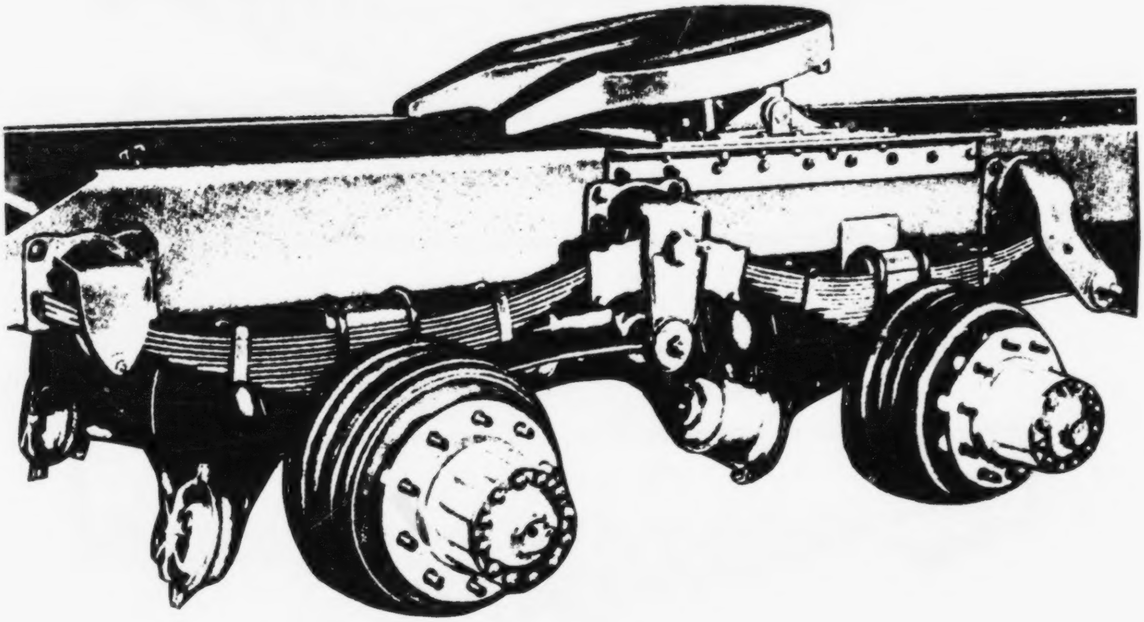
Vari-rate Spring for Variable Load


Frame
Bearing Plates
Hanger
Auxiliary Spring
Shackle
Torque Rod
Main Spring
Axle

Auxiliary or Helper Spring Suspension

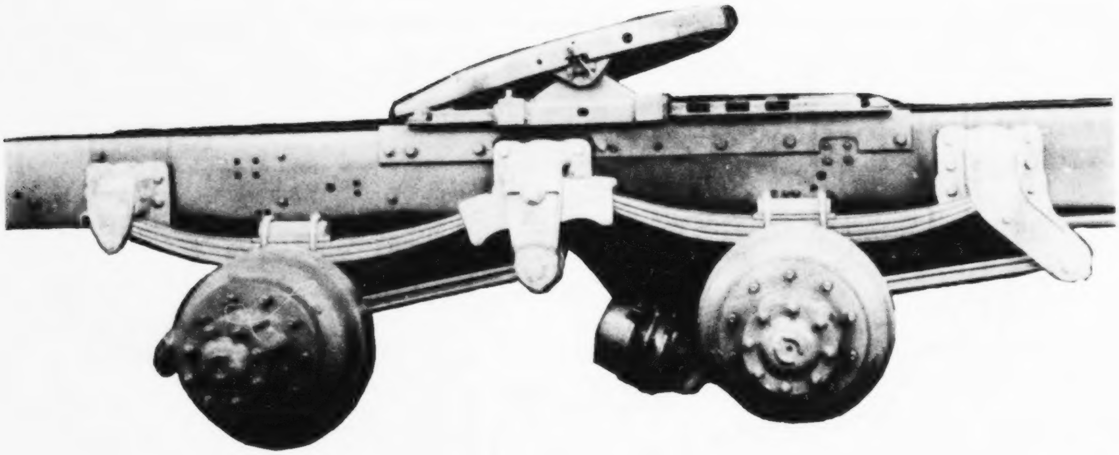
Visual 1.14

Stack Leaf Type Tandem Axle Suspension



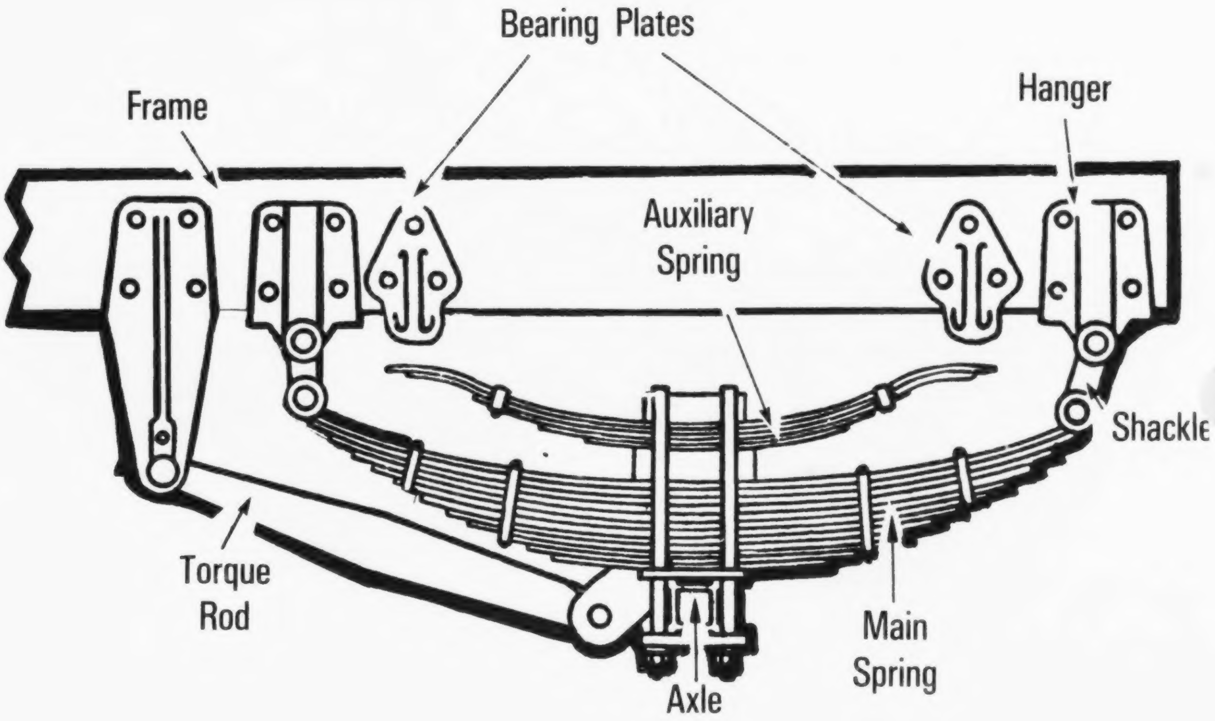
Visual 1.15

Two Leaf Tapered Spring Type Tandem Axle Suspension



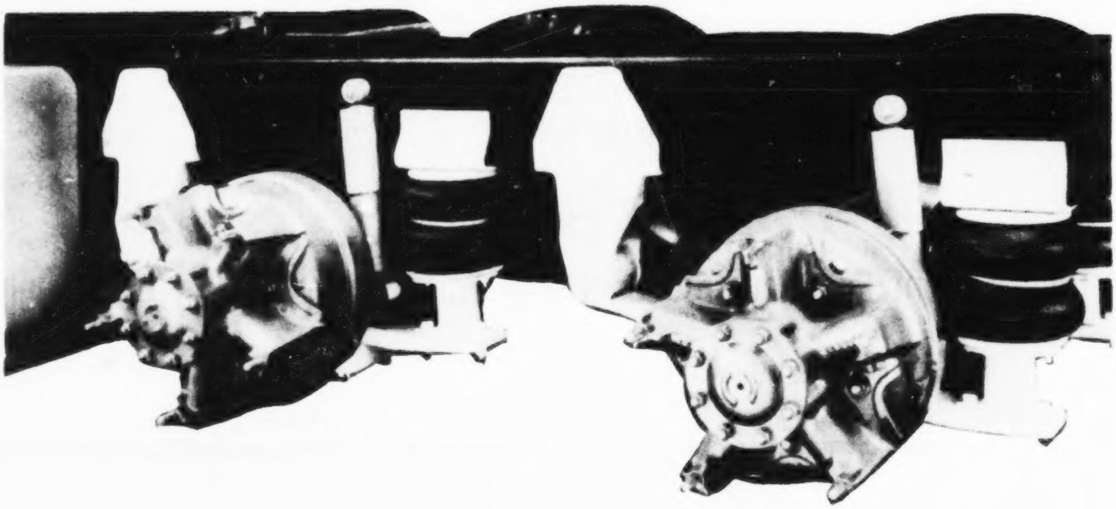
Visual 1.16

Auxiliary Springs and Torque Rods

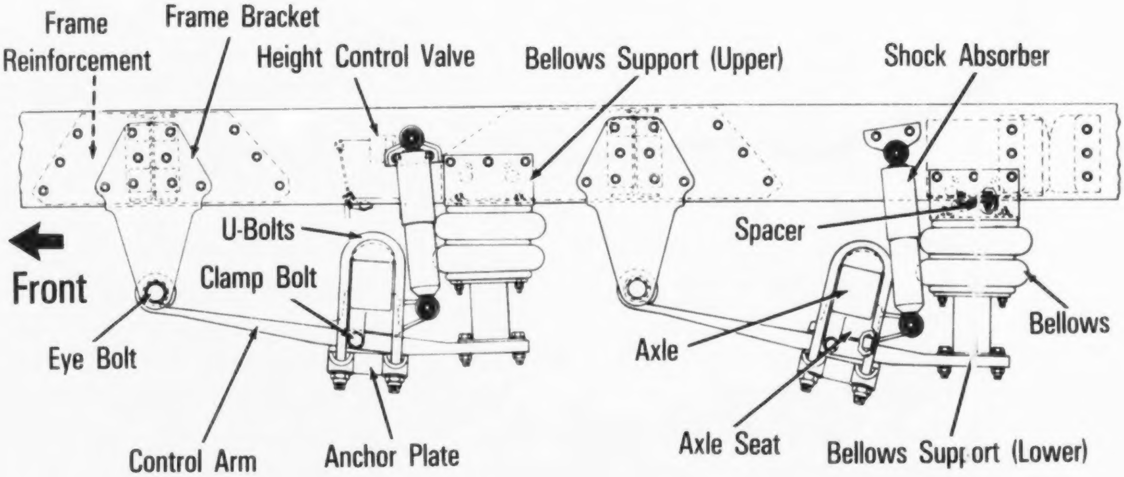

Bearing Plates
Frame
Hanger
Auxiliary Spring
Shackle
Torque Rod
Main Spring
Axle

Air Suspension System

Tandem Axle Installation



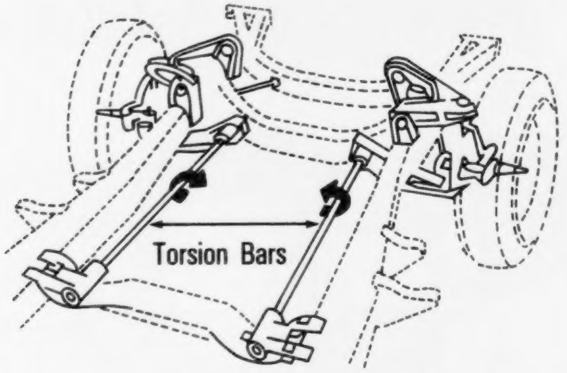
Side View


Frame Reinforcement
Frame Bracket
Height Control Valve
Bellows Support (Upper)
Shock Absorber
U-Bolts
Spacer
Front
Clamp Bolt
Bellows
Eye Bolt
Axle
Control Arm
Anchor Plate
Axle Seat
Bellows Support (Lower)

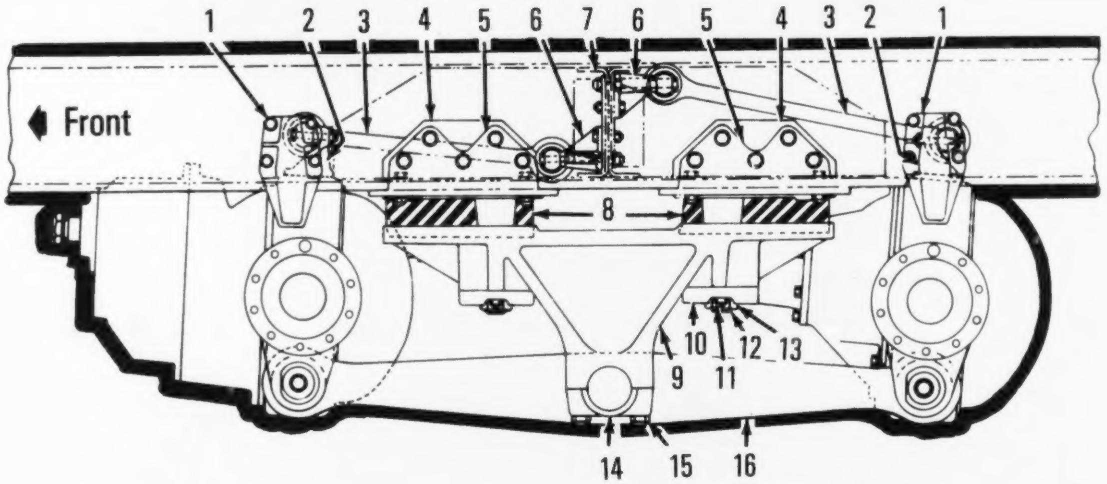
Air Suspension Diagram

Visual 1.18

Torsion Bar Suspension


Torsion Bars

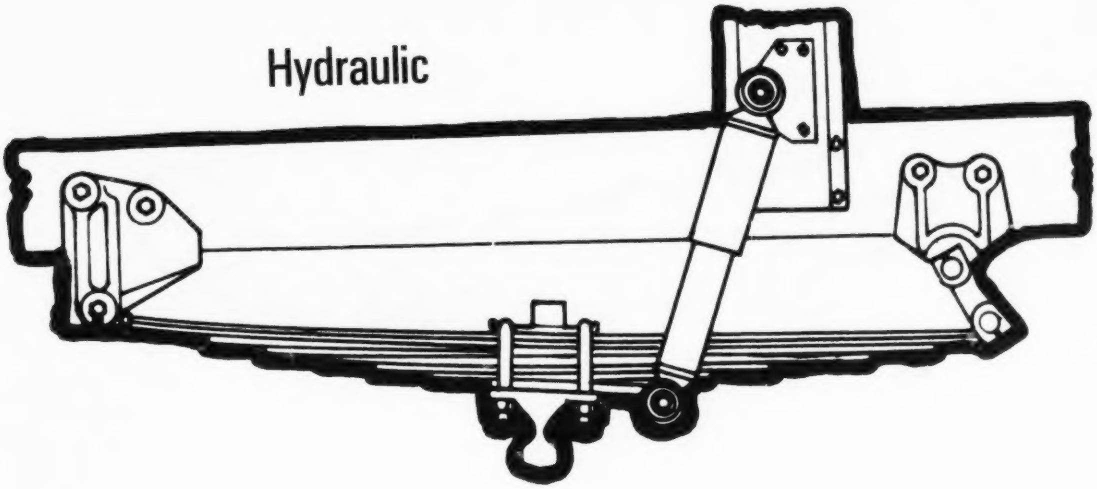
Typical Front End Construction Using Torsion Bars on an Automobile


1
2
3
4
5
6
7
6
5
4
3
2
1
Front
8
10
12
13
9
11
14
15
16

1. Axle Bumper
2. Axle Bracket (Torque Rod)
3. Torque Rod
4. Spacer
5. Frame Hanger Bracket
6. Crossmember Bracket (Torque Rod)
7. Bogie Crossmember
8. Load Cushion
9. Saddle Assembly
10. Bushing Retainer
11. Retainer Stud and Nut
12. Vertical Drive Pin
13. Pin Nut and Washer
14. Saddle Cap
15. Cap Stud and Nut
16. Equalizer Beam

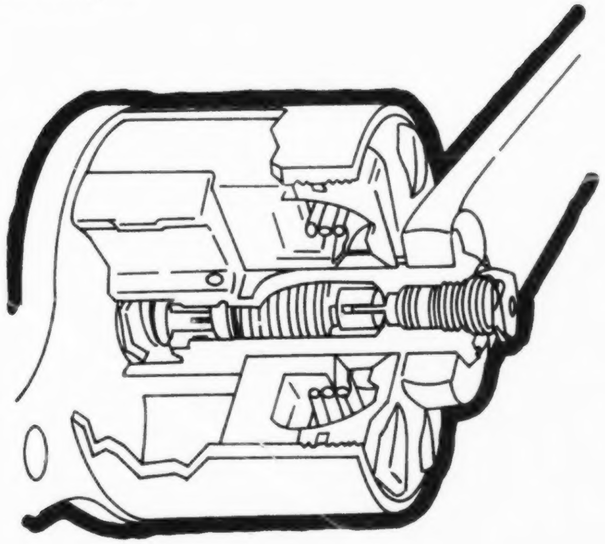
Visual 1.19

Shock Absorbers



Hydraulic

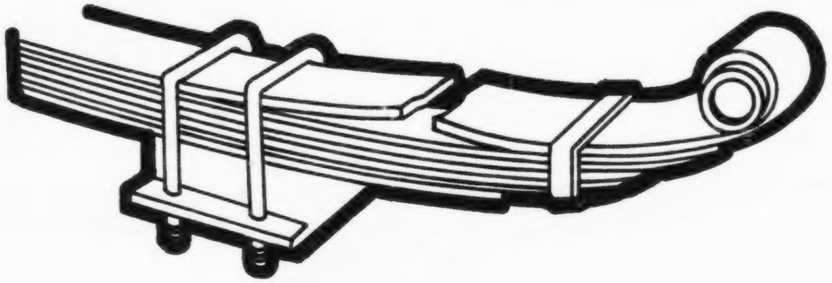
Telescopic



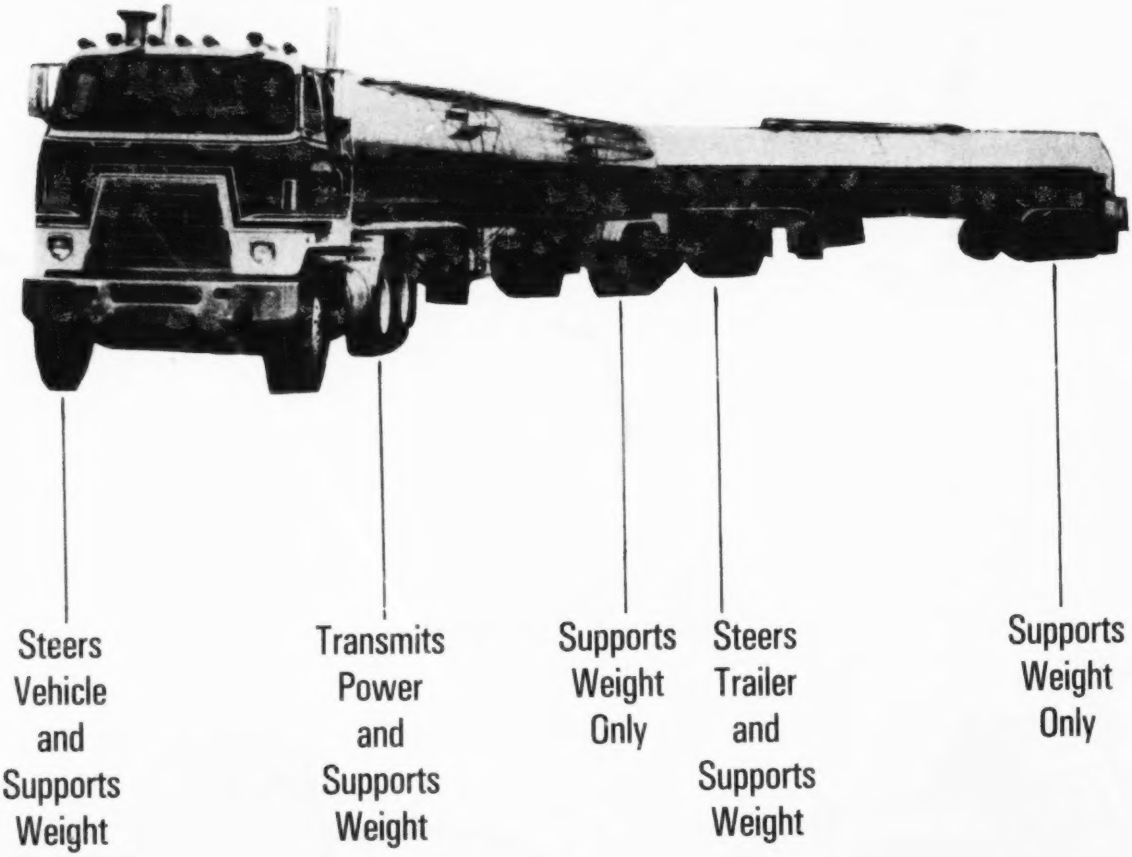
Rotary

Visual 1.20

Damaged Spring Assembly



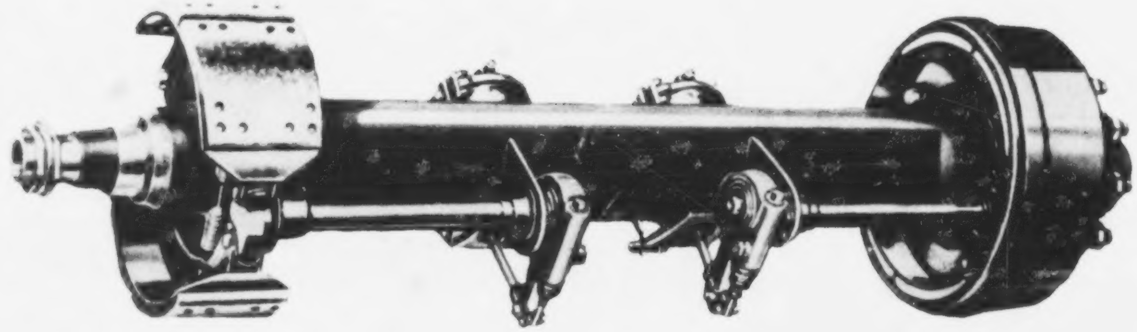
Functions of Tractor-Trailer Axles


Steers Vehicle and Supports Weight
Transmits Power and Supports Weight
Supports Weight Only
Steers Trailer and Supports Weight
Supports Weight Only

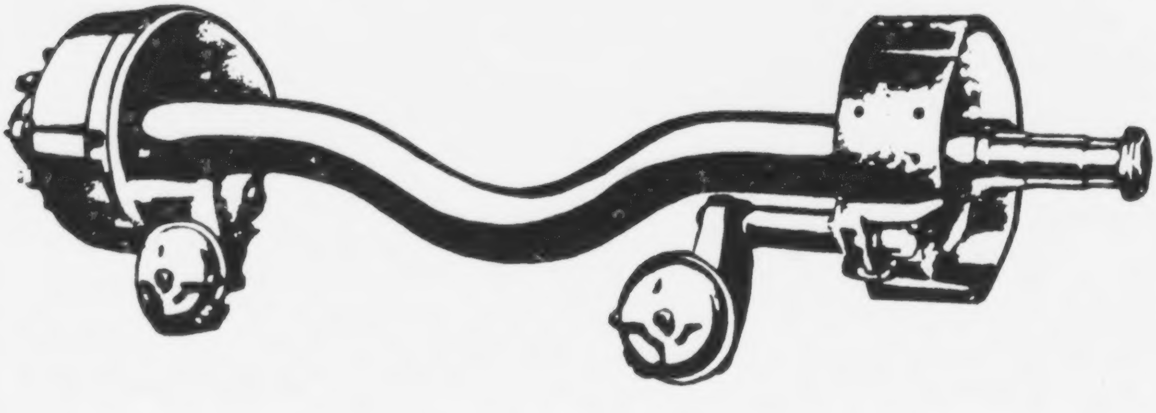
Visual 1.22

Types of Dead Axles

Straight Axle

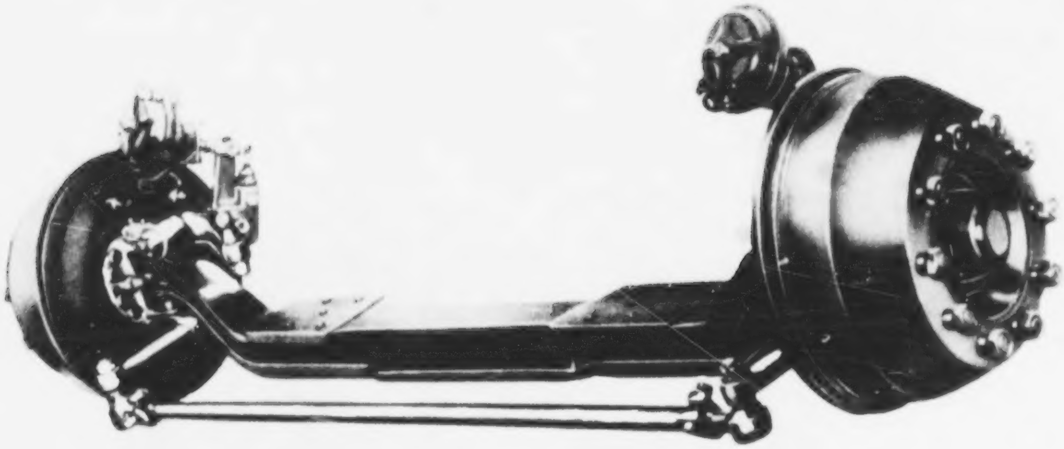


Drop Center Axle



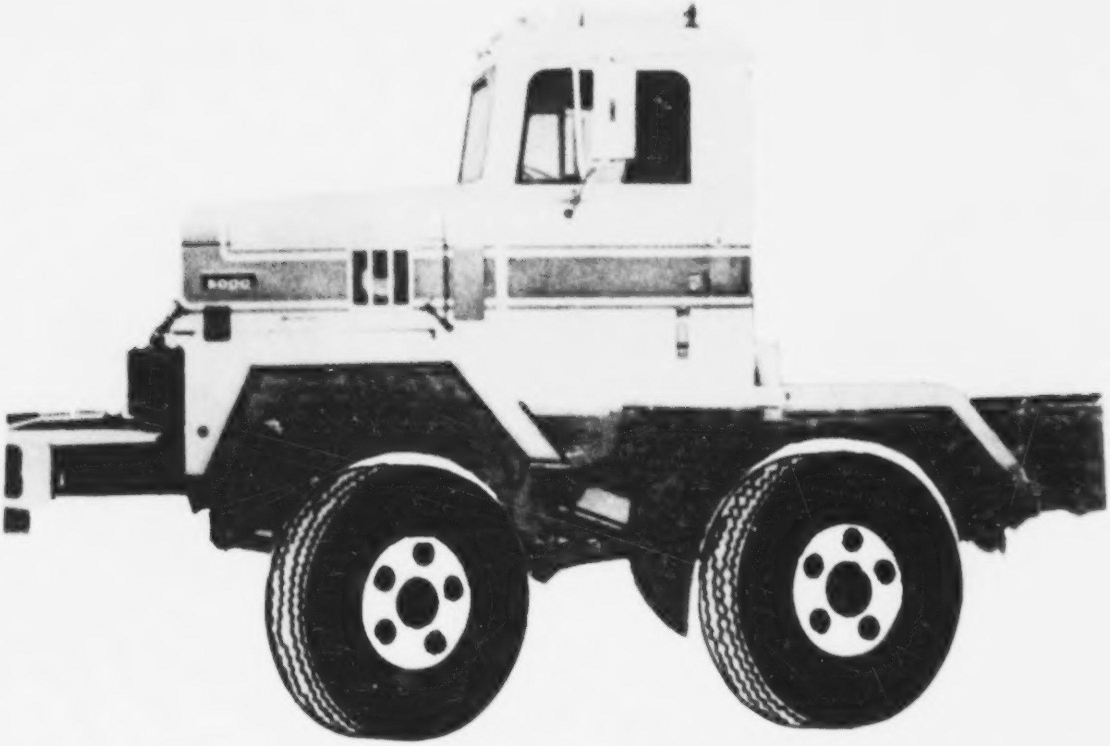
Visual 1.23

Tractor Steering Axle



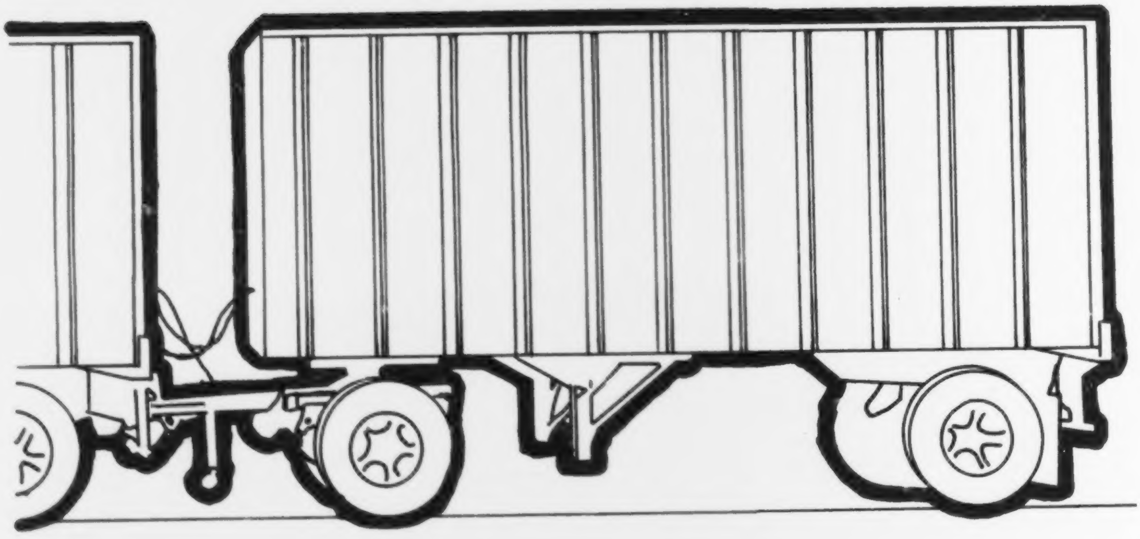
Visual 1.24

Tandem Steering Axles



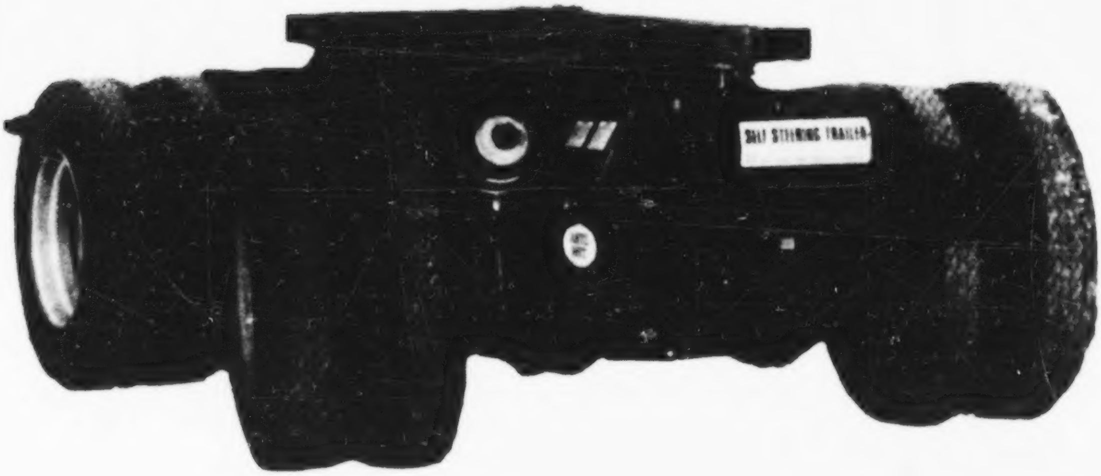
Visual 1.25

Single Axle Converter Dolly



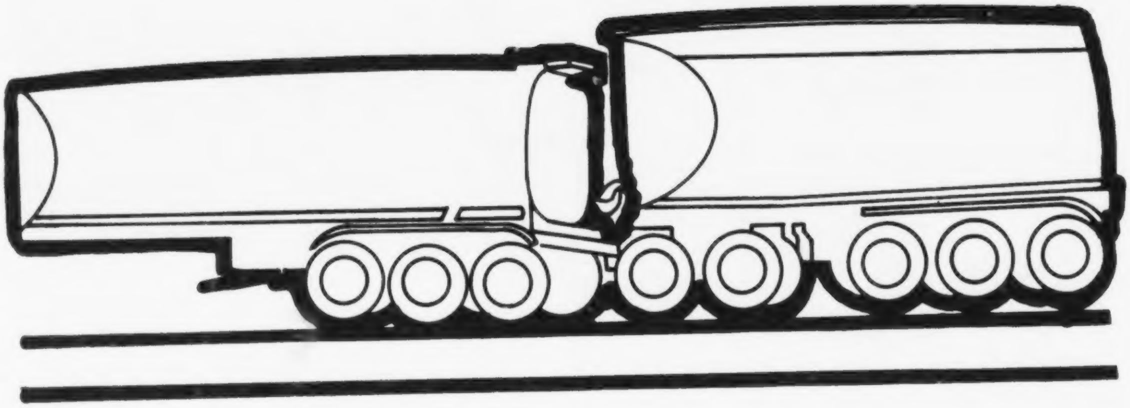
Visual 1.26

Self-Steering Semi-Trailer Axles


SELF STEERING TRAILER

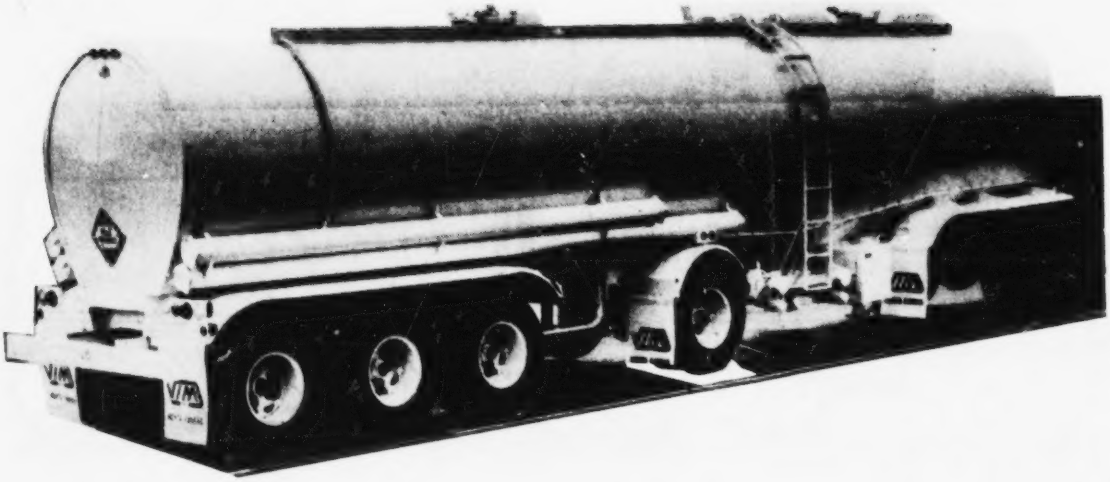
Visual 1.27

A "Michigan Train"



Visual 1.28

Retractable Axle

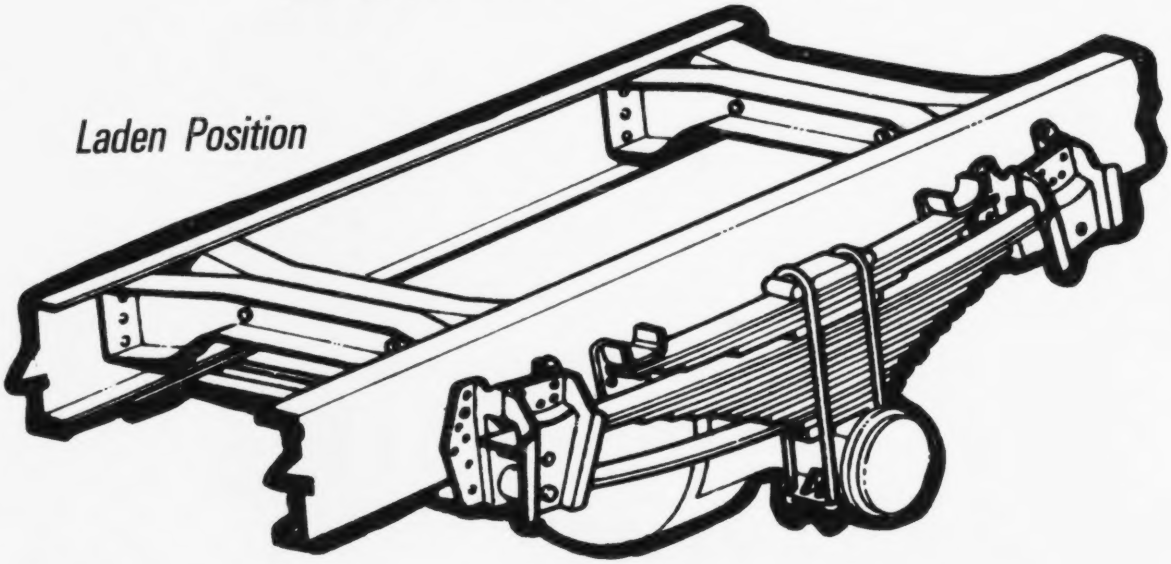


Visual 1.29

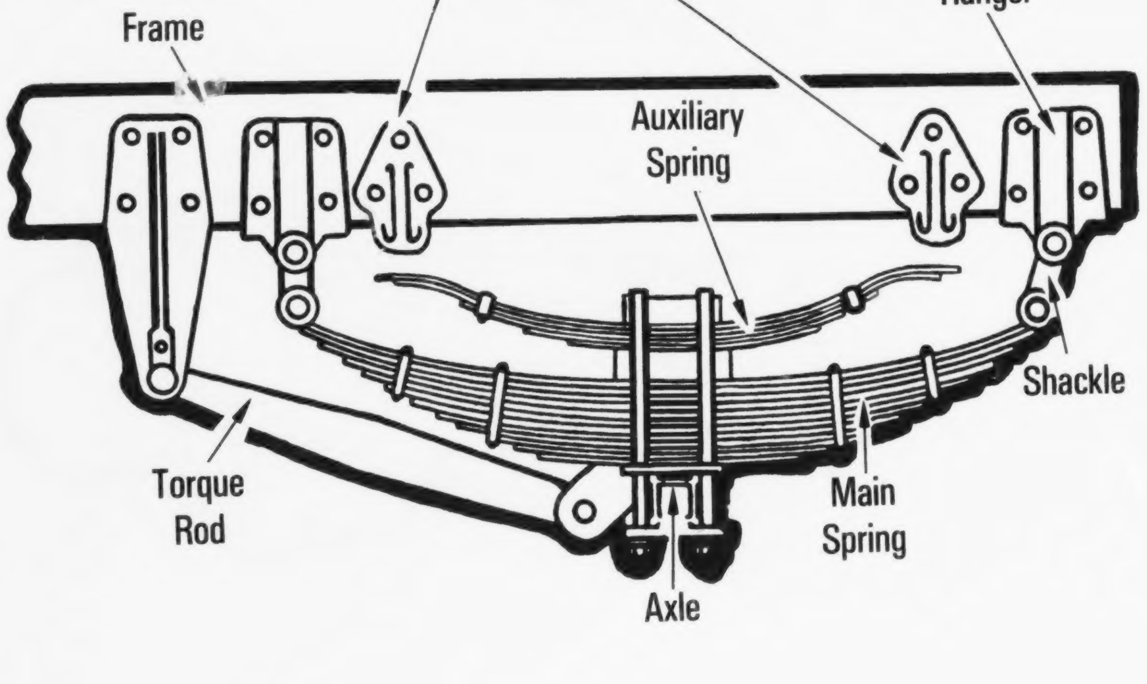
VLS Axle

(Variable Load Suspension)

Laden Position

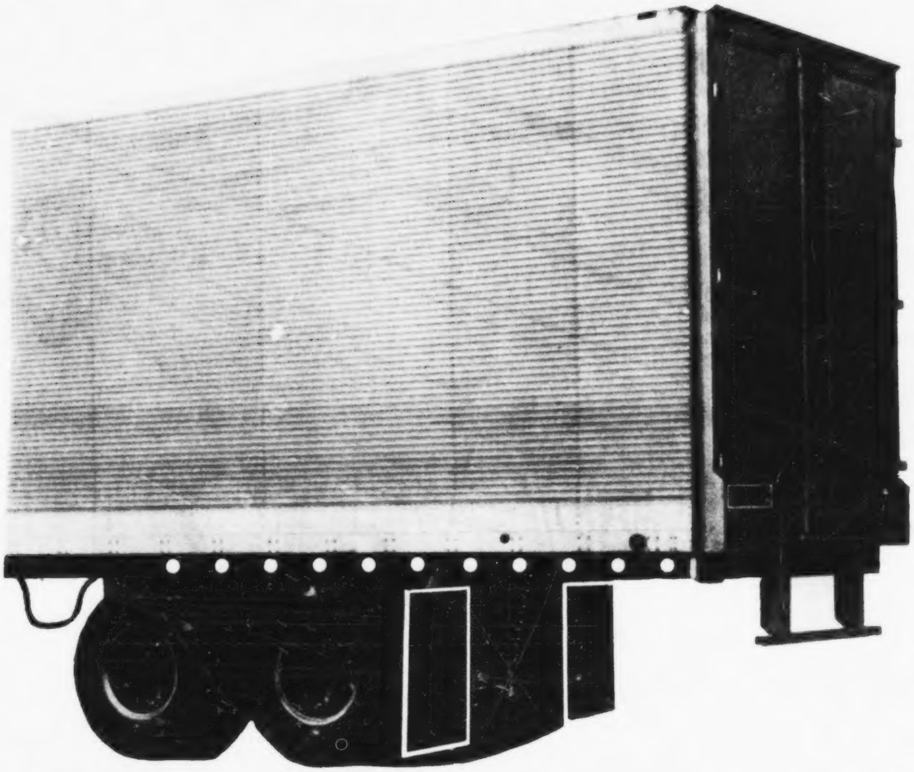


Unladen Position

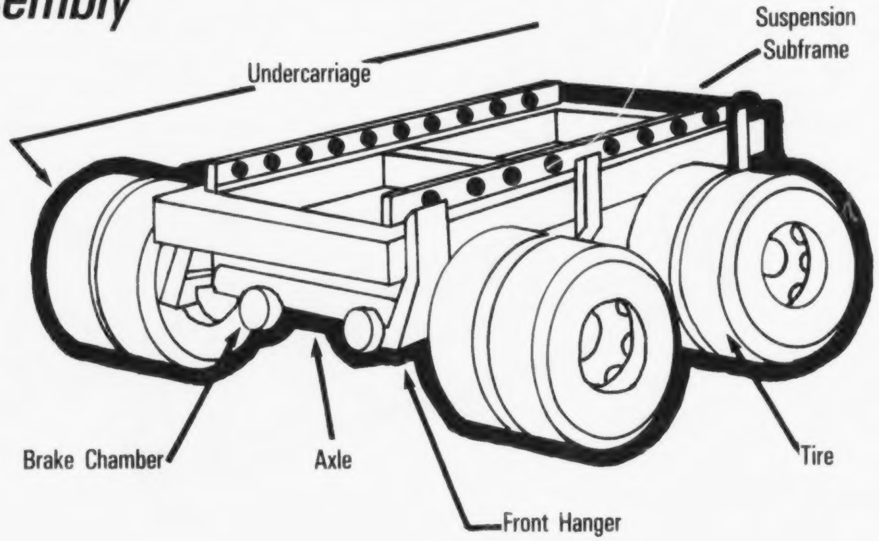

Bearing Plates
Hanger
Frame
Auxiliary Spring
Shackle
Torque Rod
Main Spring
Axle

Visual 1.30

Sliding Tandems on Semi-Trailer

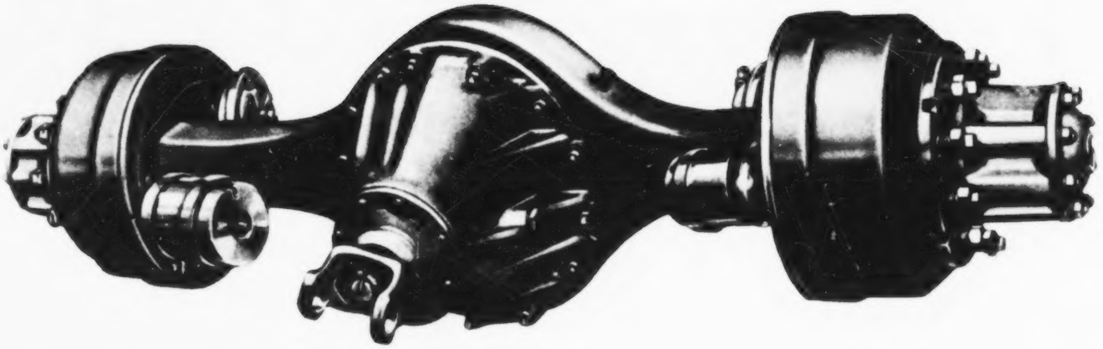


Slider Assembly


Undercarriage
Suspension Subframe
Brake Chamber
Axle
Front Hanger
Tire

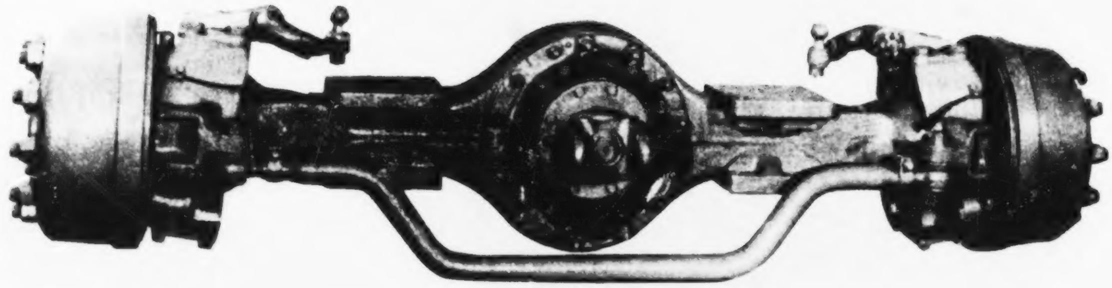
Visual 1.31

Typical Tractor Drive Axle



Visual 1.32

Powered Front Tractor Steering Axle

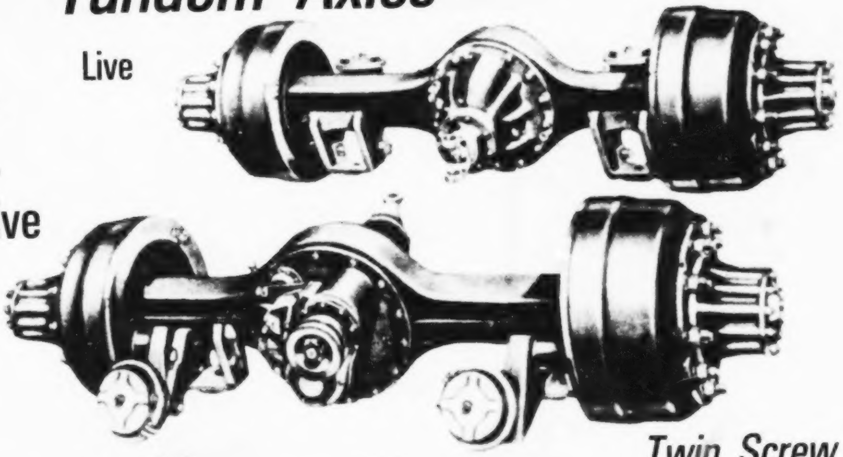


Visual 1.33

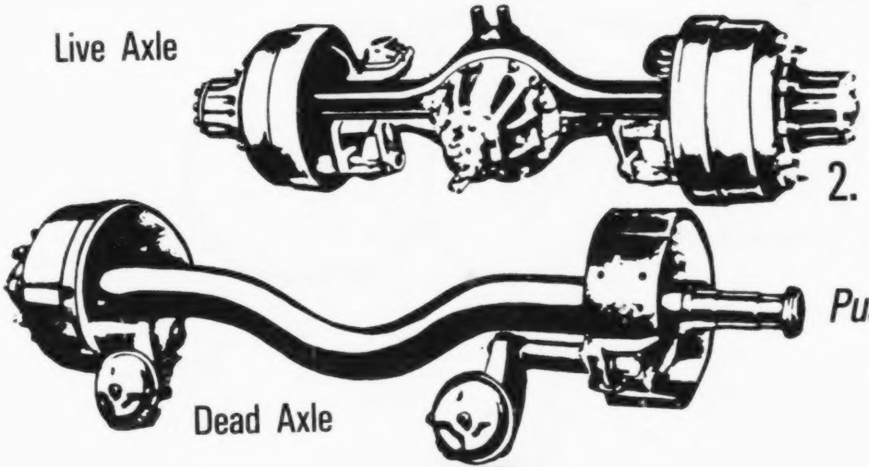
Tandem Axles

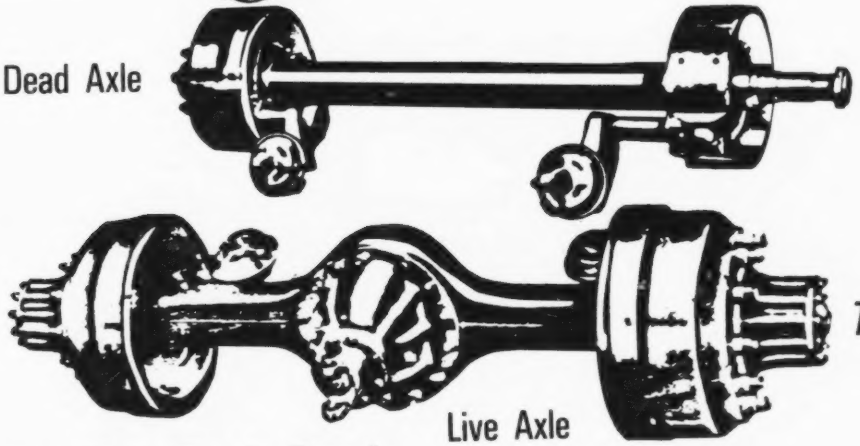
Three Types

1. Twin Screw—Both Axles Live


Live
Live
Twin Screw

2. Pusher—Front Dead, Back Live

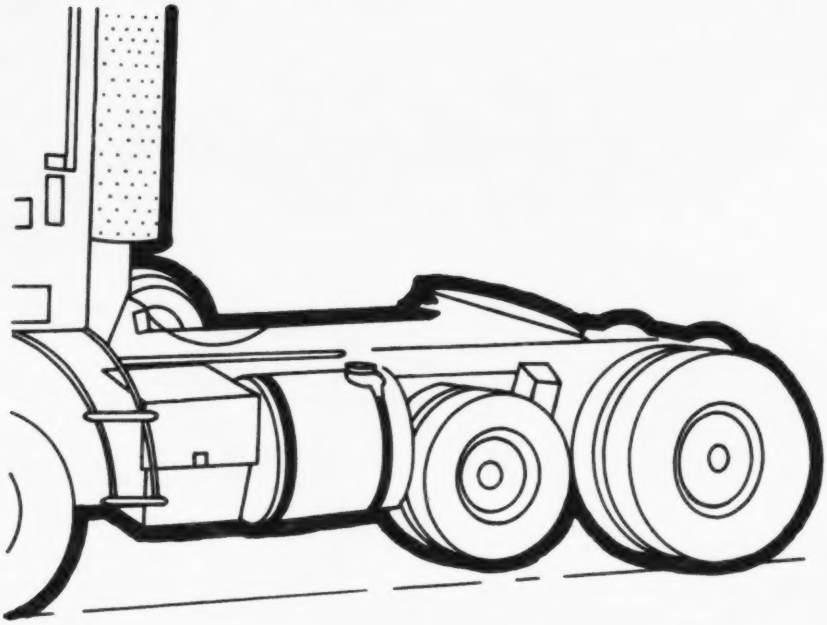

Live Axle
Pusher
Dead Axle


Dead Axle
Tag
Live Axle

3. Tag—Front Live, Back Dead

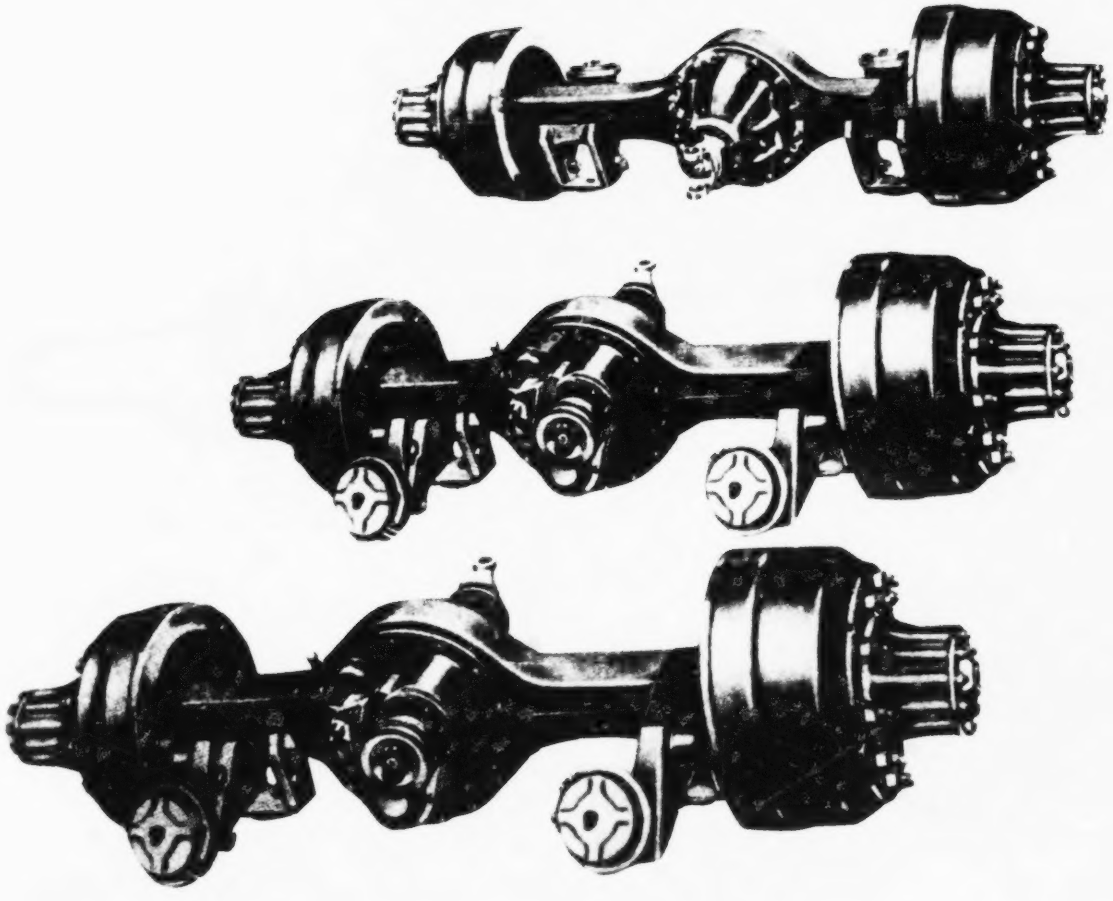
Visual 1.34

Retractable Pusher Tandem



Visual 1.35

Tri-Drive Axle Assembly

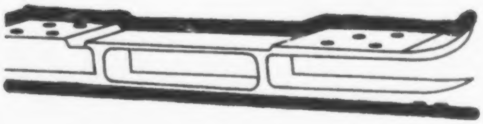


Visual 1.36

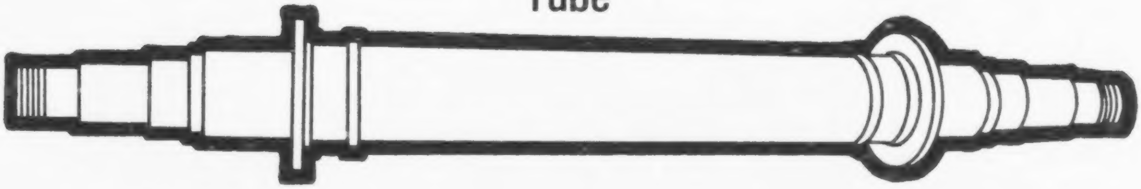
Axle Components

Dead Axles

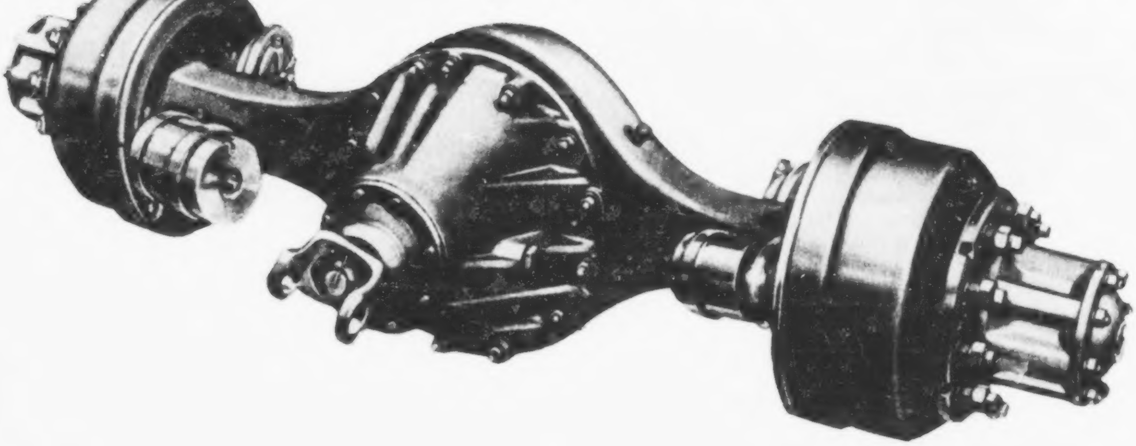
I-Beam Type



Tube



Live Axle



2. ENGINES (1 hour 10 minutes)

Introduction

This topic is designed to give students a fundamental knowledge of

- Various types of engines
- Types of engine construction
- Various engine fuels
- Basic diesel engine components and their functions
- Safety and economy of operation needed to
  - Operate vehicle in such a manner as to
    - Prolong engine life
    - Extract maximum power
    - Achieve maximum fuel economy

Visual 2.1 Engine Location

Purpose

To provide power for vehicle
- Convert fuel to heat
- Convert heat to rotary power for turning wheels and operating all other vehicle systems

Engine Systems

Visual 2.2 Internal vs. External Combustion

Basic Types

- Internal--Fuel burns inside same container which produces power
- External--Fuel burns outside of power container and "by-product" of combustion is fed into container, e.g., steam engine

Types of Internal Combustion Engine

Visual 2.3 Gasoline Engine

By fuel used

Gasoline

- Compresses a mixture of gasoline and air which is ignited by an electric spark
- Fuel and air are mixed before they enter cylinder

Visual 2.4 LPG Engine Carburetion

LPG (Liquified Propane Gas)
- Compresses mixture of fuel and air like gasoline engine
- Two differences from gasoline
  - Compressed gas cylinder added
  - Carburetor modified
  - Other same as any other gasoline engine

Visual 2.5 Diesel Engine

Diesel Engine

Compresses only air and ignition is accomplished by the heat of compression
Fuel and air are mixed inside cylinder

By Engine Construction
Reciprocating (up and down motion)

Visual 2.6 In-Line Construction Engine

In Line Construction Engine

Cylinders are lined up in one row
Can have one cylinder (lawn mower engine), or 4, 6, 8, or 12 cylinders

Visual 2.7 "V" Construction Engine

"V" Construction Engine

Cylinders are divided into two rows
  Facing each other
  Set at an angle
"V" engines can have 4, 6, 8, or 12 cylinders

Rotary (Spinning Motion) Type Engines

Visual 2.8 Gas Turbine

Gas Turbine

- Equipped with two rotors
  - Air intake (compressor)
  - Turbine rotor
- Fuel is sprayed into hot compressed air in turbine rotor Combustion takes place, forcing rotor to turn
- Spinning rotor, through a series of shafts and gears delivers power to wheels

Visual 2.9 Wankel (Rotary Combustion)

Wankel (Rotary-Combustion)

Equipped with only one rotor
Air-fuel mixture is ignited inside rotor (power container) using a spark plug
Combustion gasses exert pressure on side of rotor forcing it to turn
Spinning rotor, through a series of shafts and gears delivered power to wheels

Operating Principals of Reciprocating Engines

Visual 2.10 Four and Two Cycle Engines

Four Stroke Cycle

- Will be found in both gasoline and diesel engines
- Process
    - Stroke One--(Intake), air or air fuel mixture is introduced
    - Stroke Two--(Compression), air or air fuel mixture is compressed
    - Stroke Three--(Power), combustion takes place
    - Stroke Four--(Exhaust), gases from combustion are expelled
- Design uses one stroke of piston for each phase
    - Intake
    - Compression
    - Power
    - Exhaust

Two Stroke Cycle

- Will also be found in both gasoline and diesel engines
- Process
    - Stroke One--Intake and compression take place
    - Stroke Two--Power and exhaust occur

In this design, intake, compression, power and exhaust all take place during two strokes of the piston

Visual 2.11 Compression Ratio

Compression Ratio

- Ratio of whole cylinder volume (piston down) to volume left in cylinder after piston reaches top of stroke
- EXAMPLE: Piston at bottom of stroke--cylinder holds 100 cubic inches
    - Piston at top of stroke--cylinder can hold 10 cubic inches
    - We would say engine has a compression ratio of 10 to 1
    - The higher the compression ratio of an engine, the higher its efficiency
    - High compression ratios allow engine to get
        - More power from same amount of fuel
        - Same power from less fuel
    - Diesel engine
        - Has ability to utilize a high comrpession ratio
        - Typical ratio (diesel engine) 17 to 1
    - Gasoline engines
        - Have much lower compression ratios than diesel engines
        - Are less efficient than diesels
        - Typical ratio (gasoline engine) 10 to 1

Engine RPM

High RPM Engines

- Most older engines (60's to early 70's) have high rpm level requirements
    - Usually have a top rpm level of 2,100

    - Downshifts must occur around 1,800 rpm to keep engine from lugging
    - Engine usually must be accelerated up to maximum rpm on each up shift
- Some characteristics of high rpm engines
    - High maximum rpm levels
    - High horsepower ratings
    - High fuel consumption
    - Hotter running
    - Less fuel efficient

Low RPM Engines

- These engines have a "high torque rise"
    - Provide nearly constant horsepower through entire operating speed range
    - Allows engine to be driven in a 1,300-1,700 rpm range without lugging
    - Most efficient engine output occurs in lower rpm range
    - Each shift Starts at lower rpm
        - Increases rpm range for each gear
        - Requires less gears and less shifting of gear
- Advantage of high torque rise engines
    - Increases average road speeds
    - Reduces gear shifts
    - Decreases engine revolutions
    - Reduces fuel consumption
- Benefits
    - Faster trips
    - Less driver fatigue
    - Longer engine life
    - Greater fuel efficiency
- Most engines manufactured today use the high torque rise concept

Engine Development

- During the 60's accent was on power and speed
- The next decade energy became a problem
    - 55 mile an hour speed limit implemented
    - Fuel price increased
    - Lower rpm levels, reduced road speed and increased fuel economy became necessary

Visual 2.12 Effect of Engine Development on Today's Truck Driver

- Effect on present day truck driver
    - Creates need of greater driver awareness because of
        - Development of new driving techniques
        - New equipment
        - Mixture of the old and new engines

Components and Functions

Visual 2.13 Diesel Components

Diesel Components

- Discussion of engine components will focus upon diesel engines
  - Great majority of tractors these days have diesel engine
  - All components to be discussed will be found on both two- and four-cycle engines unless otherwise noted

Visual 2.14 Cylinder Block

Cylinder Block

- Block is composed of three parts
  - Cylinder head--forms top of cylinders
  - Block and upper crankcase--houses cylinders
  - Oil pan
    - Located below block
    - Covers the crankshaft
    - Acts as an oil reservoir (lower crankcase)
  - The block is found in both four and two stroke diesels and will be either in line or "V" shaped

Visual 2.15 Cylinders

Cylinders

- Four Stroke
  - Is a hollow tube cut into engine block and enclosed at top (cylinder head)
  - Provides an area for combustion to take place (combustion chamber)

- Two Stroke
  - A removable "wet sleeve," sometimes called a cylinder liner, is placed in block
  - A row of holes or parts are cut into the wet sleeve allowing air to be blown into cylinder
  - Wet sleeve acts as the cylinder (combustion chamber)

Visual 2.16 Pistons

Pistons

- Used on four and two stroke
  - Is a cylindrical metal plug that fits snugly up into cylinder
  - The job of the piston is two fold
    - Compresses air for combustion
    - Carries high pressure created by combustion to the crank shaft

Visual 2.17 Piston Rings

- Piston Rings
  - Cast iron rings that fit into grooves cut around the piston
  - Rings are made a little larger than diameter of cylinder wall
    - Compressed to fit in cylinder
    - Spring tension keep rings in contact with cylinder wall
  - Function is twofold
    - Upper ring--provides an air tight seal between piston and cylinder wall
    - Lower ring--scrapes off excessive oil from cylinder wall and returns it to the oil pan

Visual 2.18 Connecting Rod and Crankshaft Components

Connecting Rod

- Is a rod made of high-strength steel
- Its purpose is to connect pistons to the crankshaft

- Operation
  - Goes up and down with piston
  - Transfer motion of piston to crankshaft

Crankshaft Components

- Crankshaft is a long high strength steel rod
  - Shape provides off center (cranks) for connecting rod to attach to
  - Hangs from bottom of cylinder block
  - Supported by bearings that allow it to spin without excessive wear or friction
- Purpose
  - Changes up and down motion of connecting rod into rotary motion
  - Supplies rotary motion to drive shaft to turn wheels
  - Distributes oil to connecting rod bearings
- Operation (Illustrate operation using the visual or an engine model)
  - Downstroke
    - Piston pushes connecting rod downward
    - Crankshaft moves from top to bottom position
  - Upstroke
    - Crankshaft continues to revolve due to
      - Effect of flywheel (to be described)
      - Other cylinders that are on downstroke
    - Pushes connecting rod and piston upward
  - One revolution
    - Each time the piston and connecting rod go up and down, the crankshaft revolves once
    - Changes up and down motion to rotary motion

Flywheel

- Function
  - Smooth out the rotary motion of the crankshaft
  - Turn the crankshaft when starting the engine
- Operation
  - Gear teeth around edge of flywheel (not shown in visual) engage starter motor

When starter motor turns, flywheel revolves
Revolving flywheel turns crankshaft, causing engine to work in the same way as described in earlier discussion of "Operating Principles"
Once combustion takes place, it is the engine that causes the flywheel to turn
  Weight of flywheel keeps turning crankshaft between power strokes of each cylinder
    Smooths individual power strokes into a continuous rotation

Vibration Damper

Damper is a smaller metal disk attached to front of crankshaft
Function is two fold
  Keeps twisting action of crankshaft to a minimum
  Drives water pump and engine fan
    Pulleys are connected to damper
    Belts connect pulleys to water pump, fan, and other units

Visual 2.19 Valves and Camshaft

Valves

A valve is a long metal stem with a flat top
It opens and closes parts at top of cylinder

Four-Stroke Engines have two types of valves
  Exhaust--Lets exhaust gases escape
  Intake--Allows air into cylinder

Two-Stroke Engines
  Have two valves at top of cylinder
  Both are exhaust valves
  The intake valve is replaced by a row of holes cut into the side of cylinder

Camshaft

Driven by chain or gears from crankshaft
Camshaft rotates
  in time with crankshaft
  Turns at one-half crankshaft speed
As camshaft rotates (Illustrate, using visual)
  Cams push valve lifters
    Force valve down into cylinder
    Creates opening for intake or exhaust
  Cams release lifters
    Springs push lifters back
    Valves close

Visual 2.20 Timing Chain and Sprockets

Timing Chain and Sprockets
- Connects camshaft to crankshaft
- Determines timing of valve action, i.e., when they open and close
- Can be adjusted to change timing for maximum engine efficiency

Valve Covers
- Covers valves
- Oil splashes off cover, helping to lubricate valves

Visual 2.21 Intake Manifold

Intake Manifold
- Is an assembly of tubes through which air flows from Air filtering system to cylinders

Visual 2.22 Exhaust Manifold

Exhaust Manifold
- Is a series of tubes carrying exhaust gases from engine to the exhaust pipe
- Exhaust manifold is attached to the side of cylinder head
- (Additional information can be found in the "Air Intake And Exhaust" portion of this lesson)

Visual 2.23 Water Jacket

Water Jacket
- Spaces that surround combustion chamber and cylinder walls
- Provide passages in which coolant is circulated to cool engine
- (Additional information can be found in the "Cooling system" portion of this lesson)

Fuel Pump Injectors

Visual 2.24 Injectors

Fuel pump injector is a pump tht injects fuel into cylinders
Fits into top of combustion chamber (like spark plug)
Must be timed (like spark plug) to inject fuel at proper time in cycle.
Timing accomplished by camshaft and injector rack
(Injectors will be covered in detail in "Fuel System" portion of this lesson)

Engine Fuels

Engines are designed to run on specific types of fuel
- Diesel fuel
- Gasoline
- LPG (Liquified Petroleum Gas--in compressed form)
- Alcohol-gasohol
- Benzine
- Methane gas

Some gasoline engines are modified to run on LPG

- Must not use fuel other than that engine is designed to use
    - Could cause extensive engine damage
    - Could cause fire
- Driver's operating vehicles with diesel engines must watch fuel supply closely
    - Not every service station carries diesel fuel
    - May be a long distance between fuel supplies
    - Can be difficult to restart engines when fuel supply has been exhausted
- Fuel will be discussed more fully under "Fuel Systems" in this lesson

How Components Work

Engine components work in conjunction with one another, forming a working unit, to provide
- Power to run vehicle
- Power to operate all other vehicle systems

Visual 2.25 Four-Stroke Cycle

Four-Stroke Cycle Engine

Intake

- Intake valve--opens allowing air to enter cylinder
- Piston--moves from top of cylinder to bottom, drawing air into cylinder
- Connecting rod--transfers piston movement to crankshaft
- Crankshaft--makes 1/2 turn

Compression

- Intake valve--closes, sealing off cylinder port, preparing for combustion
- Piston--moves back up cylinder compressing air (causing the air to become very hot due to being compressed)
- Water jacket--coolant is circulating around combustion chamber and cylinder walls cooling piston and cylinder
- Connecting rod--transfers piston movement to crankshaft
- Crankshaft--completes one revolution Power

Power

- Intake valve--closed, (seals port), ready for combustion
- Exhaust valve--closed (seals port)
- Injectors--inject fuel into hot compressed air in cylinder; combustion takes place
- Piston--expanding gases from combustion, push piston back down cylinder (this stroke provides power to run engine)
- Connecting rod--transfers downward power of thrust of piston to crankshaft
- Crankshaft--converts up and down movement of piston to rotary motion, providing power to drive train components
- Intake valve--closed
- Exhaust valve--opens allowing gases from combustion to escape
- Piston--moves back up cylinder pushing exhaust gases out opening created by exhaust valve

- Connecting rod--transfers piston movement to crankshaft
- Crankshaft--completes second revolution, cycle ready to start again

Visual 2.26 and Visual 2.27 Two-Stroke Cycle

Two-Stroke Cycle Engine

For a two cycle engine to operate a blower must be added to blow air into holes cut in cylinder wall

Stroke One

- Exhaust valves--open
- Intake holes--uncovered, air is blown into cylinder
- Piston
  - Moving upward, pushes exhaust gases out valve opening 1/4 way up cylinder--exhaust valves close, air holes covered
  - Piston compresses air
- Connecting rod--transfers piston movement to crankshaft
- Crankshaft--makes 1/2 revolution

Stroke Two

- Exhaust valves--closed
- Intake holes--covered
- Injectors
  - Inject fuel into hot compressed air
  - Combustion takes place
- Piston
  - Gases from combustion push piston back down cylinder
  - Halfway down, valves open, exhaust gases start to escape
  - Three-quarters of way down, air holes uncovered, fresh air is blown into cylinder
- Connecting rod--transfers piston movement to crankshaft
- Crankshaft--finishes one revolution, cycle complete

Locating and Recognizing Problems

On all pretrip, enroute and post trip vehicle inspections, it is vital that the driver protect the engine by

Looking For

Pretrip

- Too much tension on fan belts
  - Can cause water pump failure and a heat damaged engine
  - Can cause fan bearing failure
- Too much slack in fan belts
  - Can cause belts to slip and thus not pump enough air or coolant
  - Can cause the fan to turn slower than it should and not cool engine properly
- Signs of coolant leakage
- Signs of lube oil leakage

Enroute
- Loose, cracked or otherwise damaged engine mounts
- Engine oil pressure and/or temperature too high or too low
- Engine oil level too high or too low
- Engine coolant pressure and/or temperature too high or too low
- Engine coolant level too low
- Signs of clogged, leaking or restricted primary and secondary oil, coolant and air intake filtration systems
- Engine exhaust temperatures either too high or too low
- Engine exhaust smoke color
  - Black smoke
    - Not enough air to completely burn the fuel
    - Engine is lugging
  - White smoke (sometimes grey)
    - Normal in really cold weather until engine warms up
    - If it doesn't disappear, there is a problem
  - Blue smoke--engine is burning its lubricating oil

Listening For

- Any sounds of roughness, misfiring or other signs of malfunctioning
- Any knocking, banging, rapping, or thumping sounds, not usually heard in this type of engine
- When strange sounds occur, the first actions to take are
  - Check the dash panel guages for confirmation of a malfunction
  - Check exhaust smoke

Feeling For

- Any unusual or different vibrations or surges or impulses from the
  - engine could be caused by an engine that is severely damaged and is about to seize up
  - When such symptoms occur, the first action is to check instruments for confirmation of a malfunction

Smelling For

- Any smells of burning oil, rubber or other material that may signal an impending engine malfunction

Consequences of Engine Malfunction

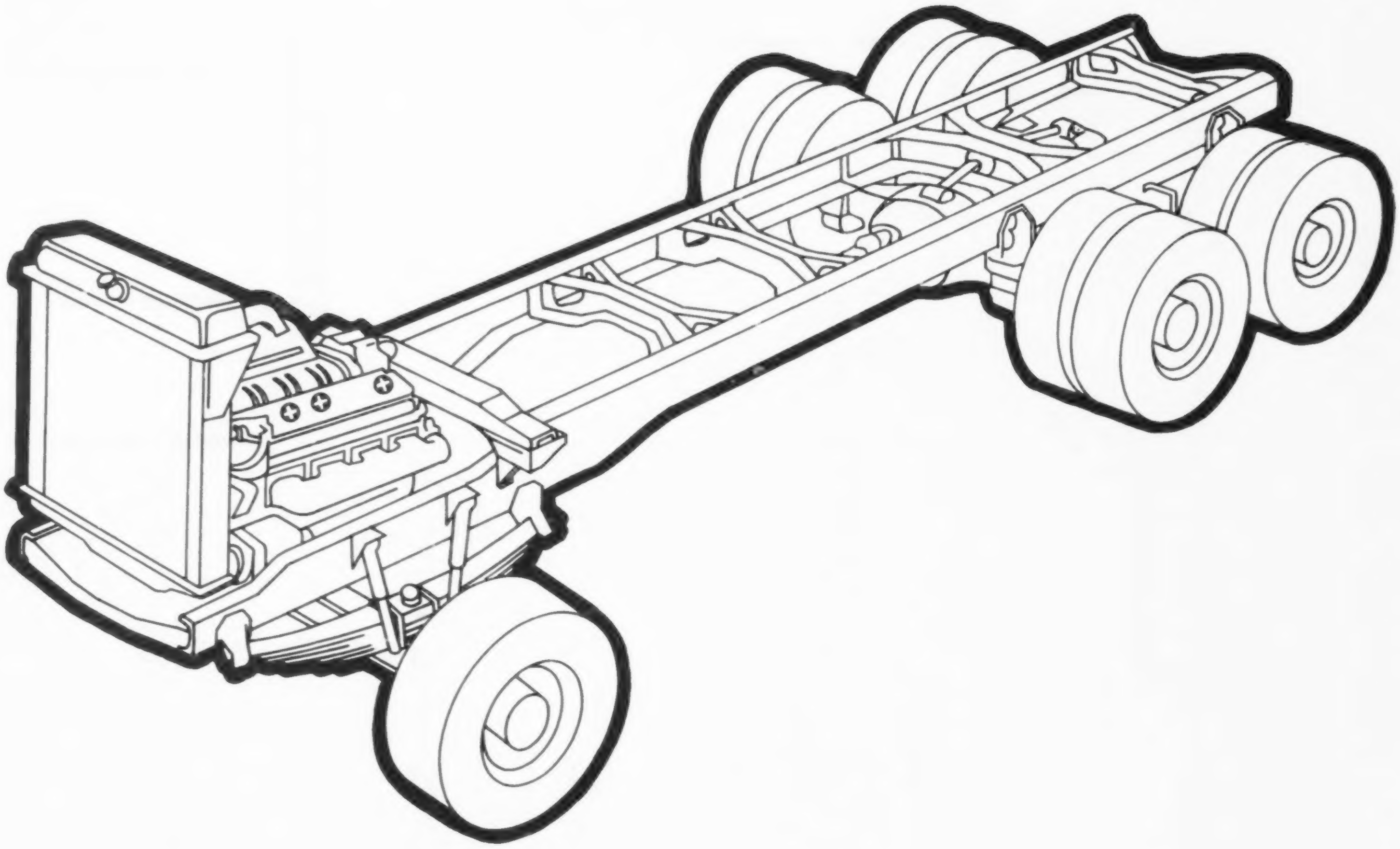
- Continued operation of malfunctioning engine can cause
  - Engine damage, necessitating expensive overhaul
  - Engine seizure
    - Explosion could result
    - Could cause serious injury or fatality
  - Loss of braking
    - Failed engine cannot operate air compressor
    - Will result in loss of
      - Air brakes
      - Air operated clutch and/or transmission

Recap

It is essential that drivers know the type of engine in their rig and its operating characterisitcs.

- Drivers unfamiliar with an engine cannot assume it is the same as in the last vehicle they operated
- Not being familiar with an engine's operating characteristics can result in
    - Wasted fuel
    - Improper and unnecessary shifting
    - Thousands of dollars worth of damage to the engine
- In operating a vehicle with an unfamiliar engine, drivers should read operators manual and get expert advice on
    - RPM operating range
    - Required temperatures and pressures
    - Engine limitations
- During vehicle inspections and while driving
    - Look, listen, and feel for signs of engine malfunction
    - Stop at the first sign of trouble and shut down engine to prevent serious damage and possible accident
- It is the driver's responsibility, as a professional, to take care of engine and its accessories

Engine Location

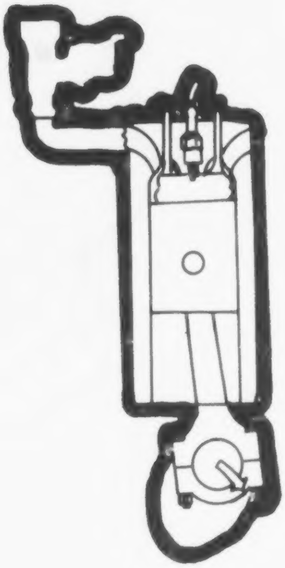


Visual 2.2

Internal Vs. *External* Combustion

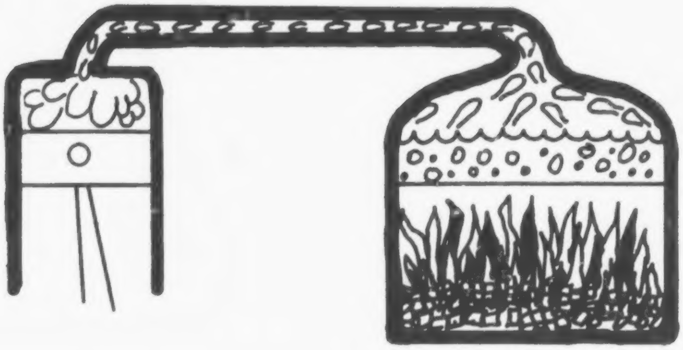
Internal – Fuel Burns Inside Same Container Which Produces Power

Gasoline
or → Engine
Diesel



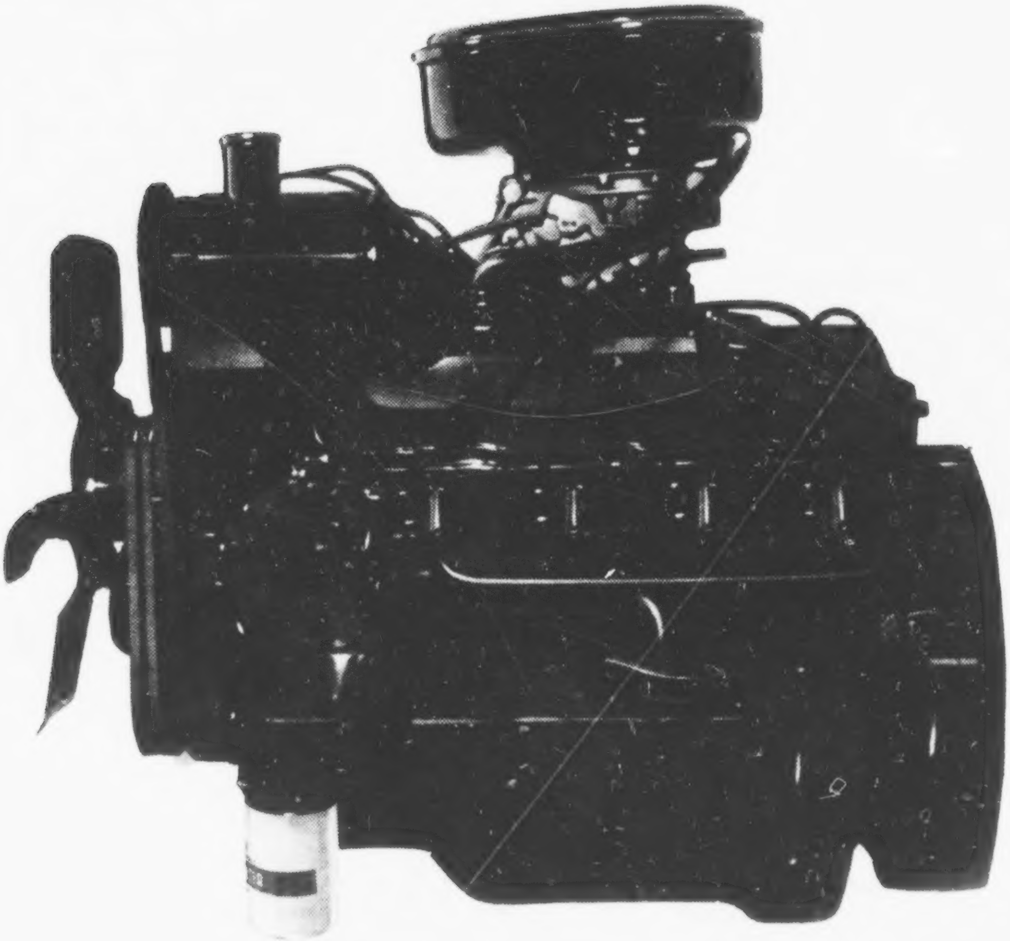
External –Fuel Burns Outside of Power Container

Steam Engine →



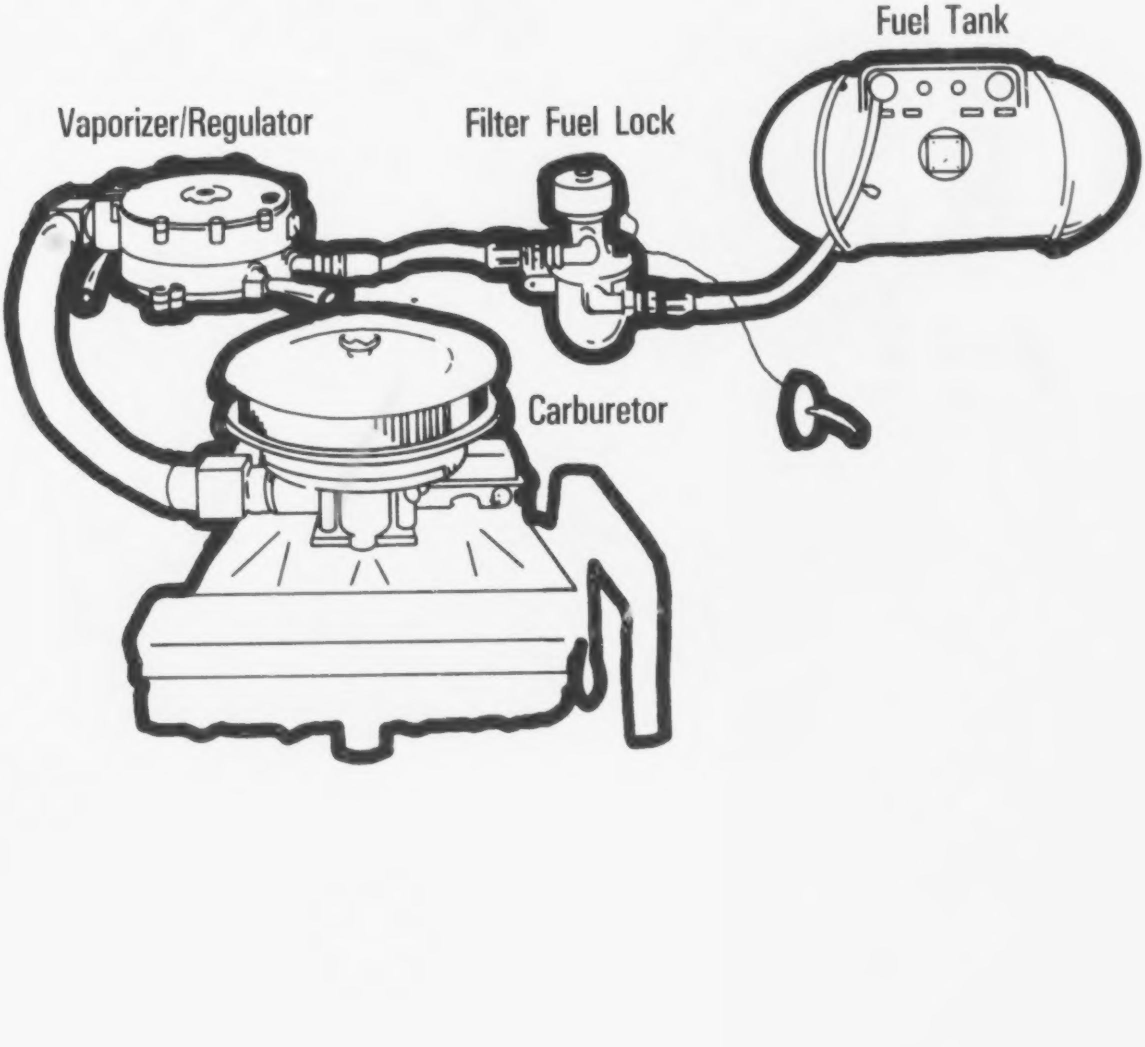
Visual 2.3

Gasoline Engine



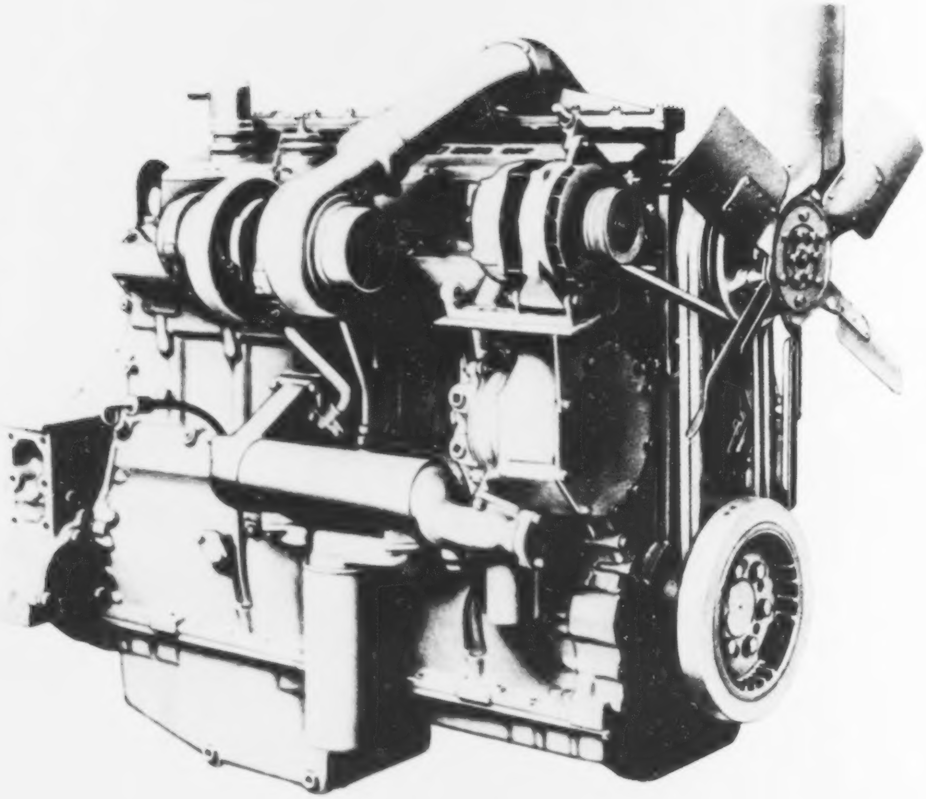
Visual 2.4

LPG Engine Carburetion


Fuel Tank
Vaporizer/Regulator
Filter Fuel Lock
Carburetor

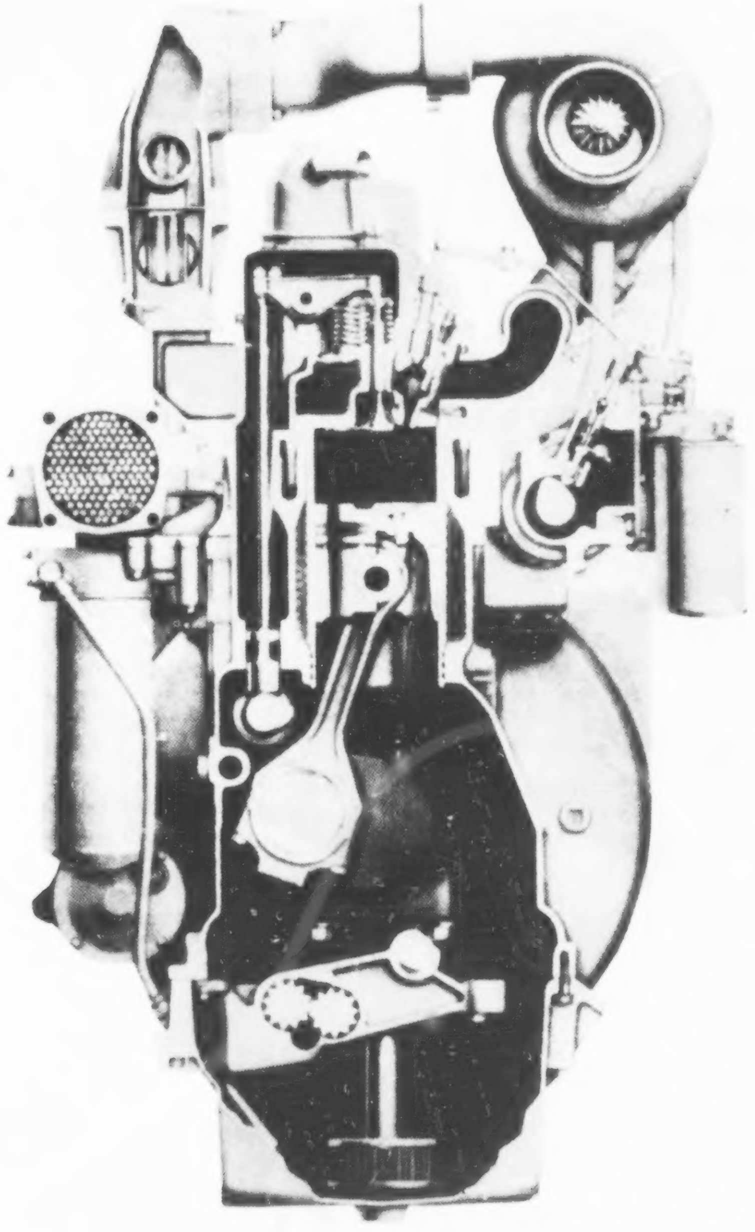
Visual 2.5

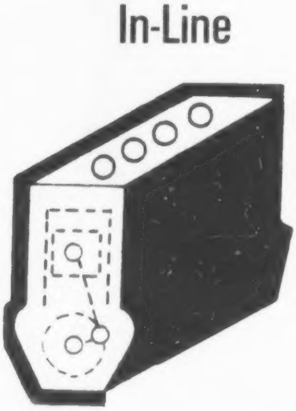
Diesel Engine



Visual 2.6

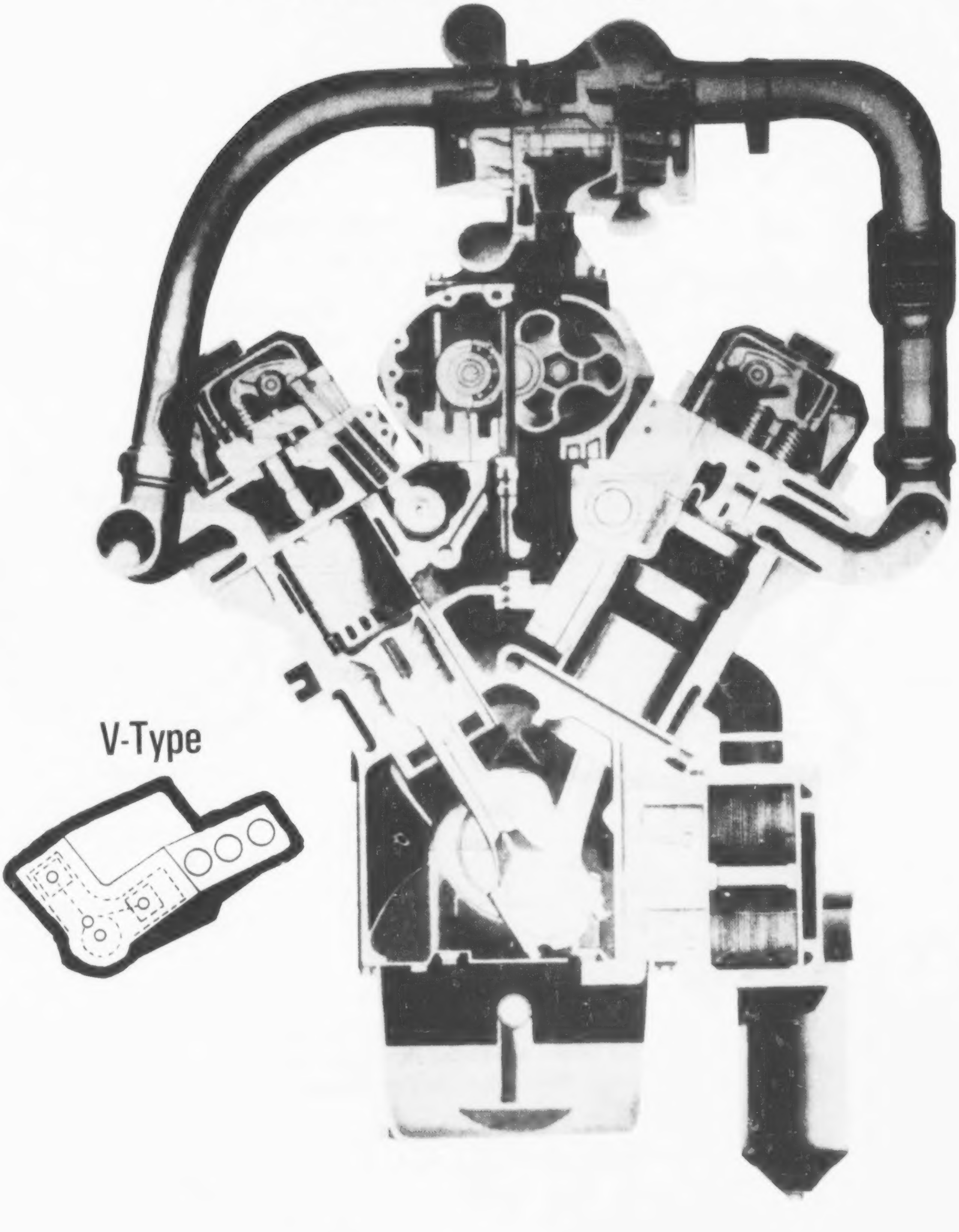
In-Line Construction Engine





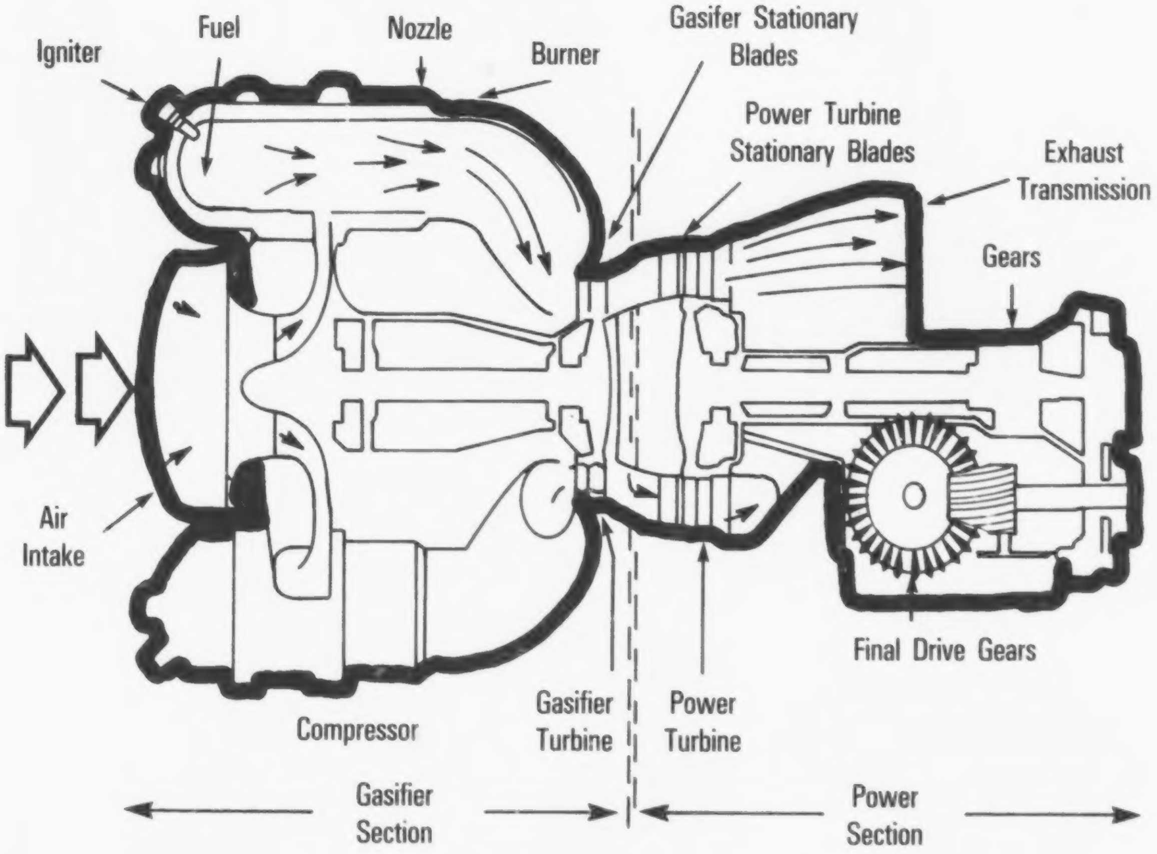
Visual 2.7

V Construction Engine



Visual 2.8

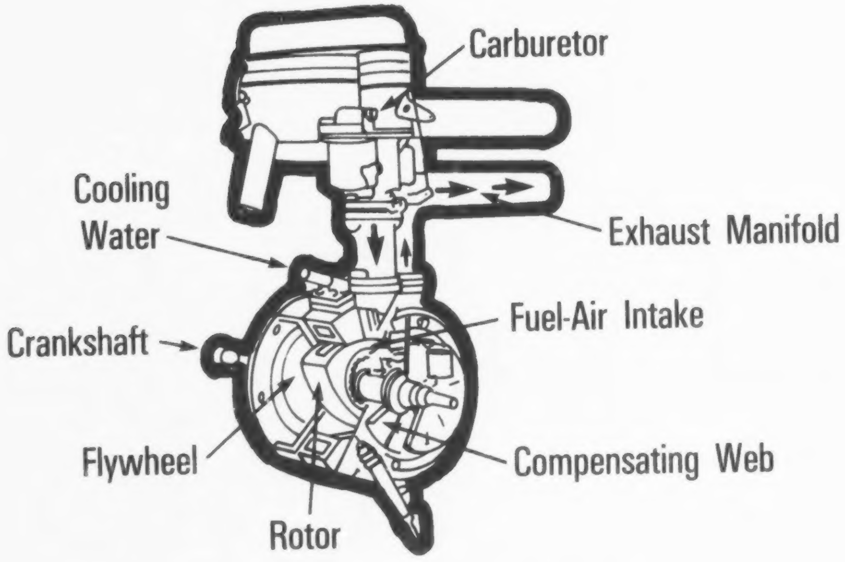
Gas Turbine Engine


Igniter
Fuel
Nozzle
Burner
Gasifer Stationary Blades
Power Turbine Stationary Blades
Exhaust Transmission
Gears
Air Intake
Final Drive Gears
Compressor
Gasifier Turbine
Power Turbine
Gasifier Section
Power Section

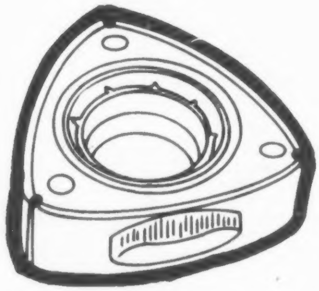
A Simplified Picture of a Gas Turbine. The Gasifier Section Burns Fuel and Delivers the Resulting High-Pressure Gas to the Power Section Where It Spins the Power Turbine.

Visual 2.9

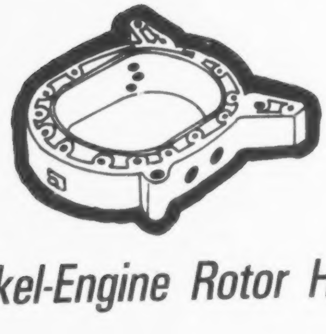
Wankel (Rotary Combustion Engine)


Carburetor
Cooling Water
Exhaust Manifold
Fuel-Air Intake
Crankshaft
Flywheel
Compensating Web
Rotor

A Cutaway View of a Wankel Engine



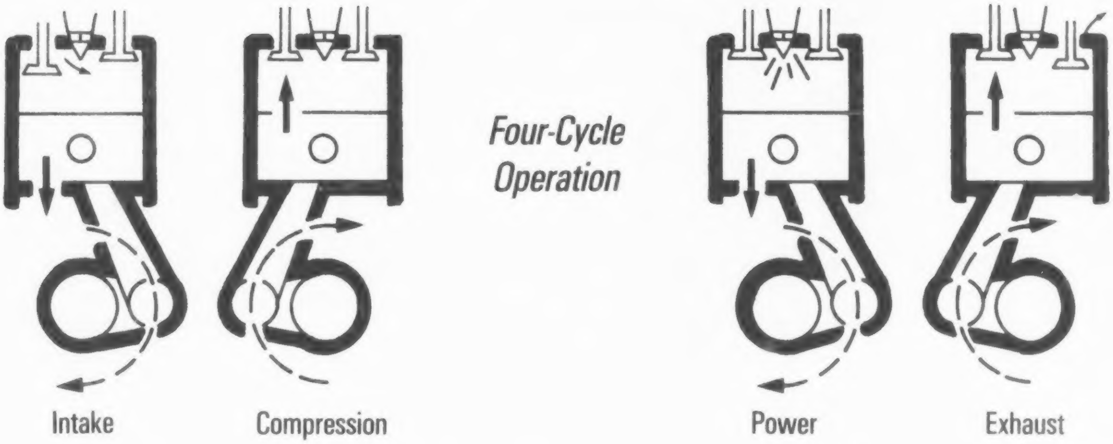
A Wankel-Engine Rotor

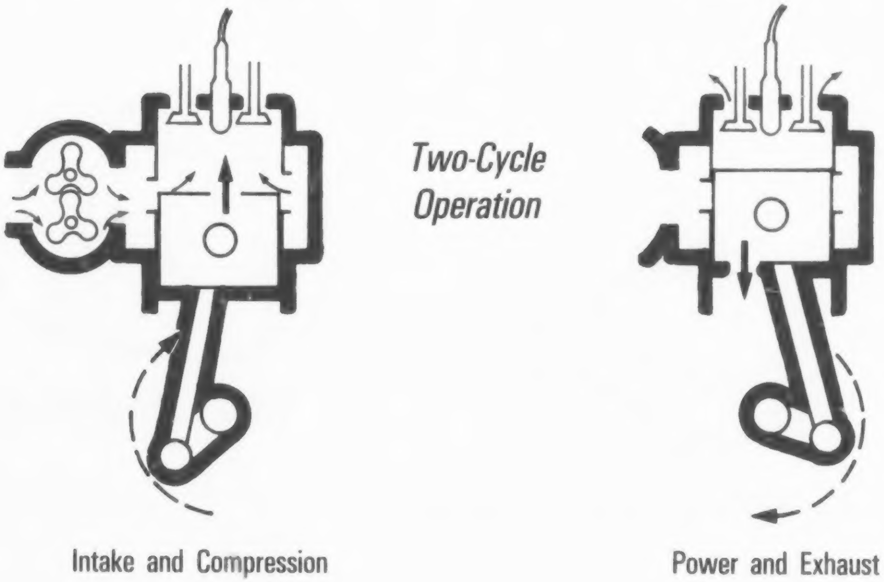


A Wankel-Engine Rotor Housing

Visual 2.10

Four and Two Cycle Engines


Intake
Compression
Four-Cycle Operation
Power
Exhaust

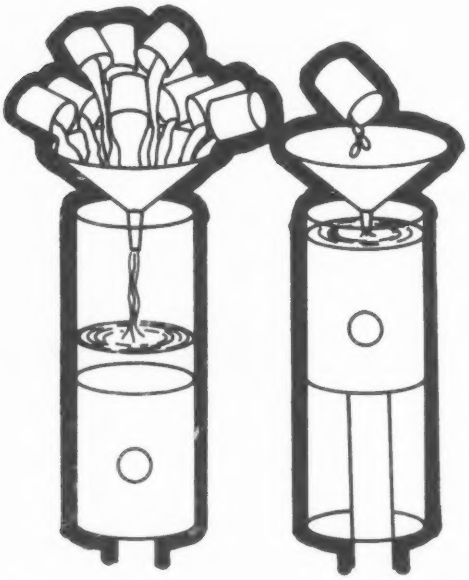

Intake and Compression
Two-Cycle Operation
Power and Exhaust

Visual 2.11

Compression Ratio

Gasoline Engine

Typical Ratio 10 to 1



10 With the Piston at the Bottom
1 With the Piston at the Top

Diesel Engine

Typical Ratio 17 to 1

Visual 2-12

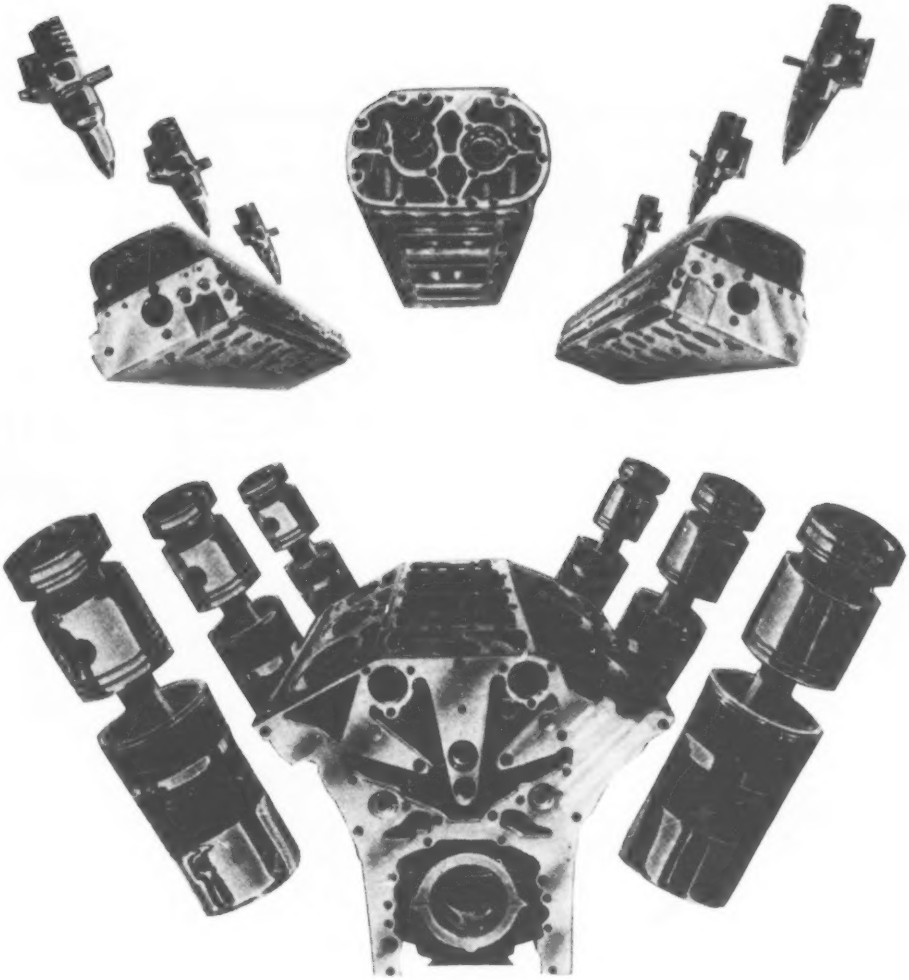
Effect of Engine Development on Today's Truck Driver

Created Need for Greater Driver Awareness Because of:

- New Driving Techniques Required
- New Equipment
- Mixture of Old With the New Type Engines

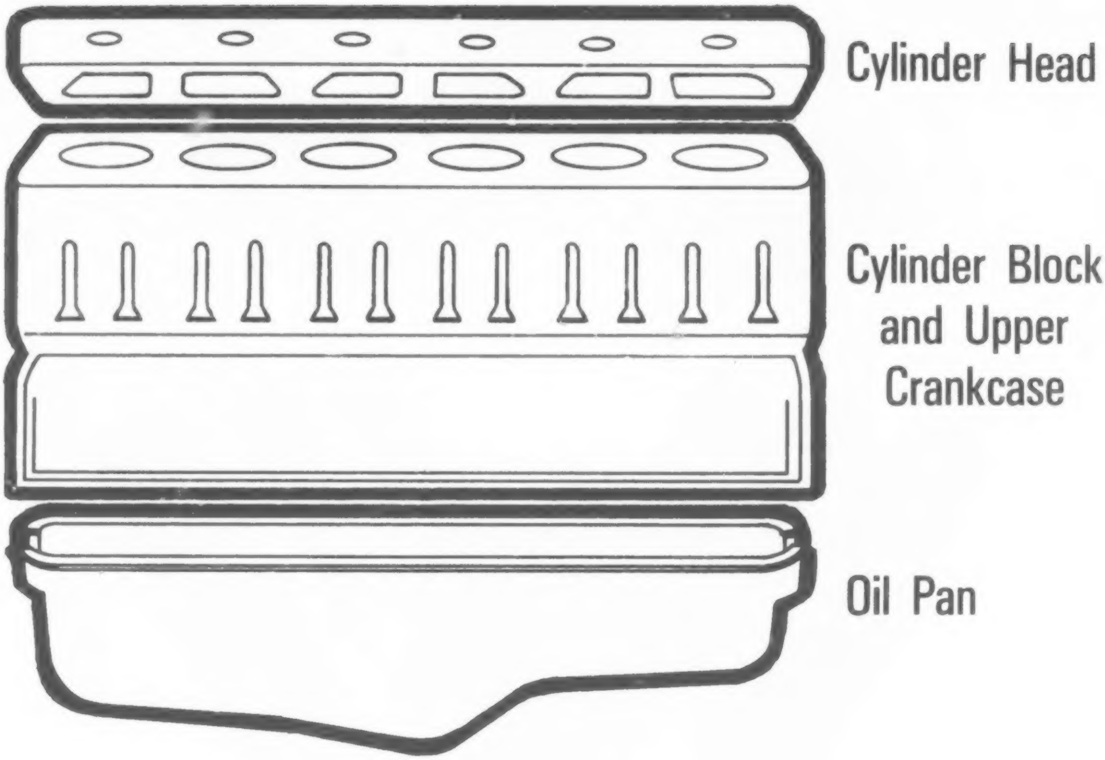
Visual 2.13

Diesel Components



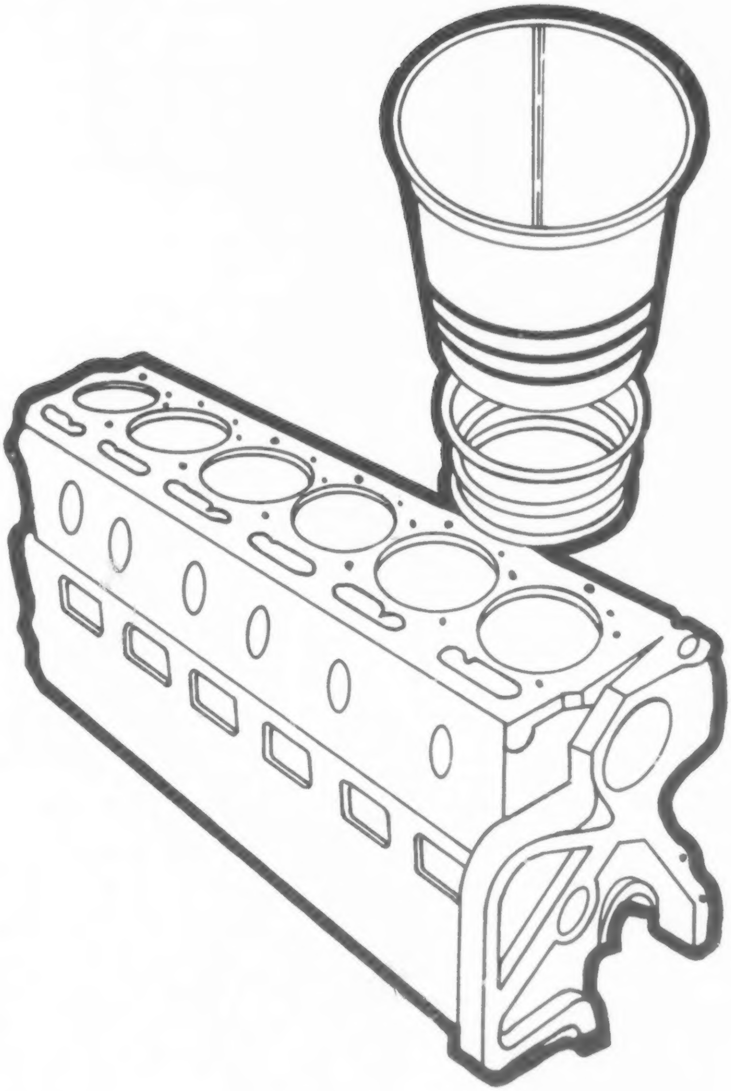
Visual 2.14

Cylinder Block


Cylinder Head
Cylinder Block and Upper Crankcase
Oil Pan

Visual 2.15

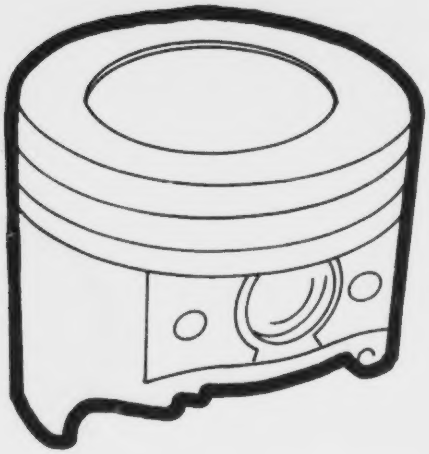
Cylinders



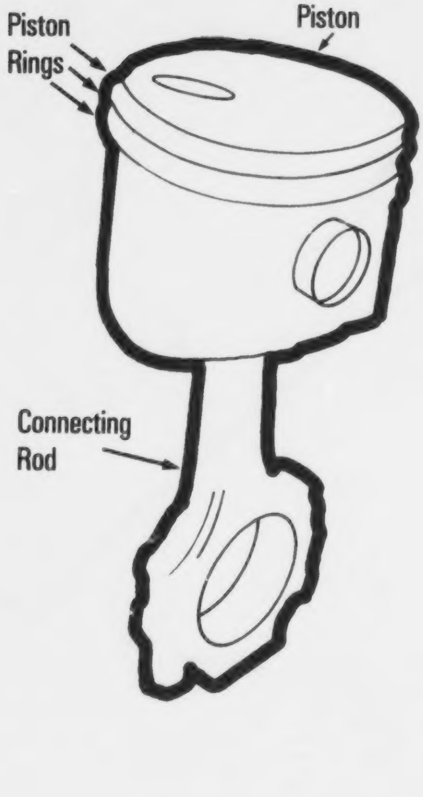
Liner in
Position
for
Installation
in the
Block
Bore.

Visual 2.16

Pistons



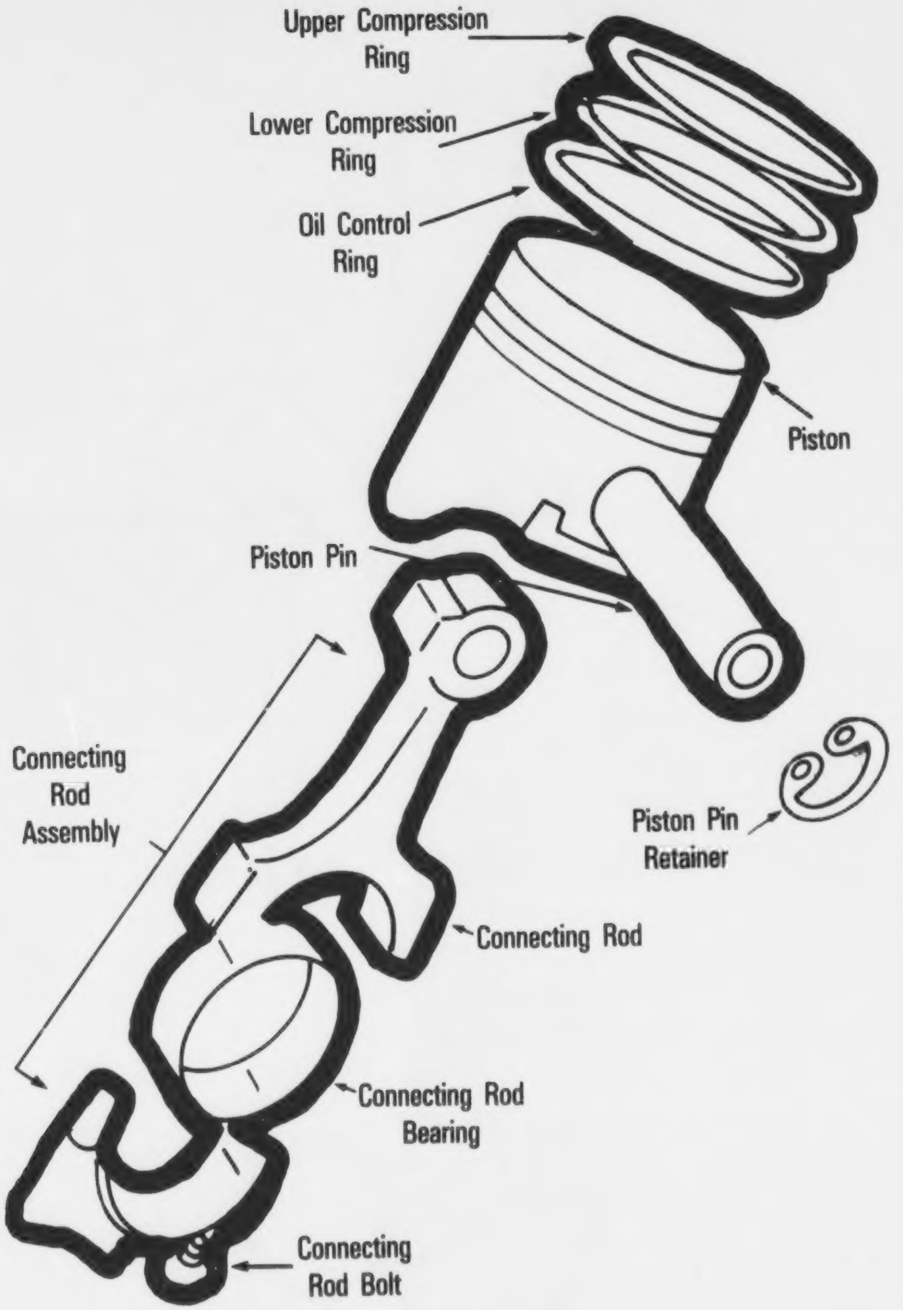
Piston Head


Piston Rings
Piston
Connecting Rod

Piston Head
With Connecting Rod

Visual 2.17

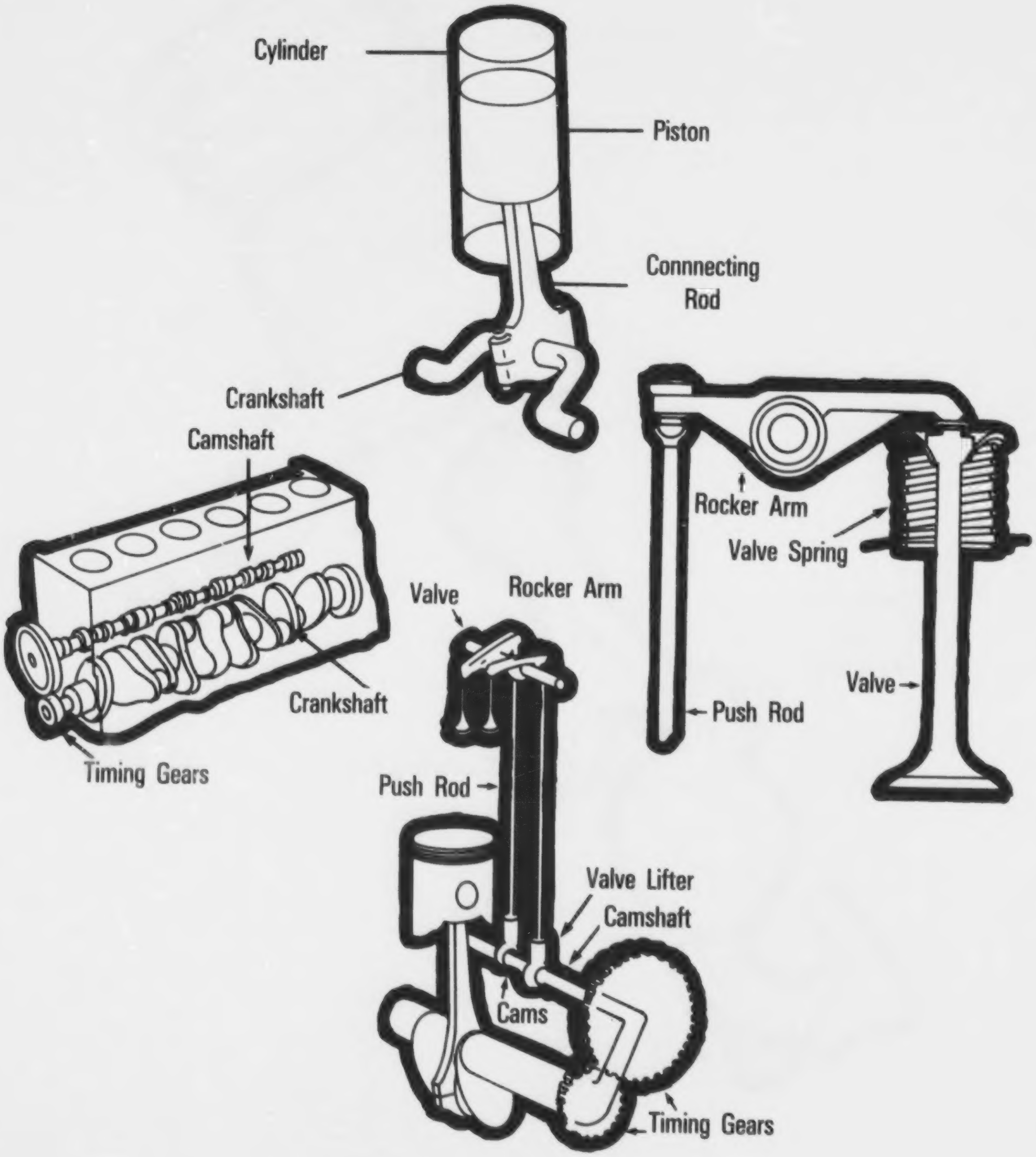
Piston Rings


Upper Compression Ring
Lower Compression Ring
Oil Control Ring
Piston
Piston Pin
Connecting Rod Assembly
Piston Pin Retainer
Connecting Rod
Connecting Rod Bearing
Connecting Rod Bolt

READEX FICHE

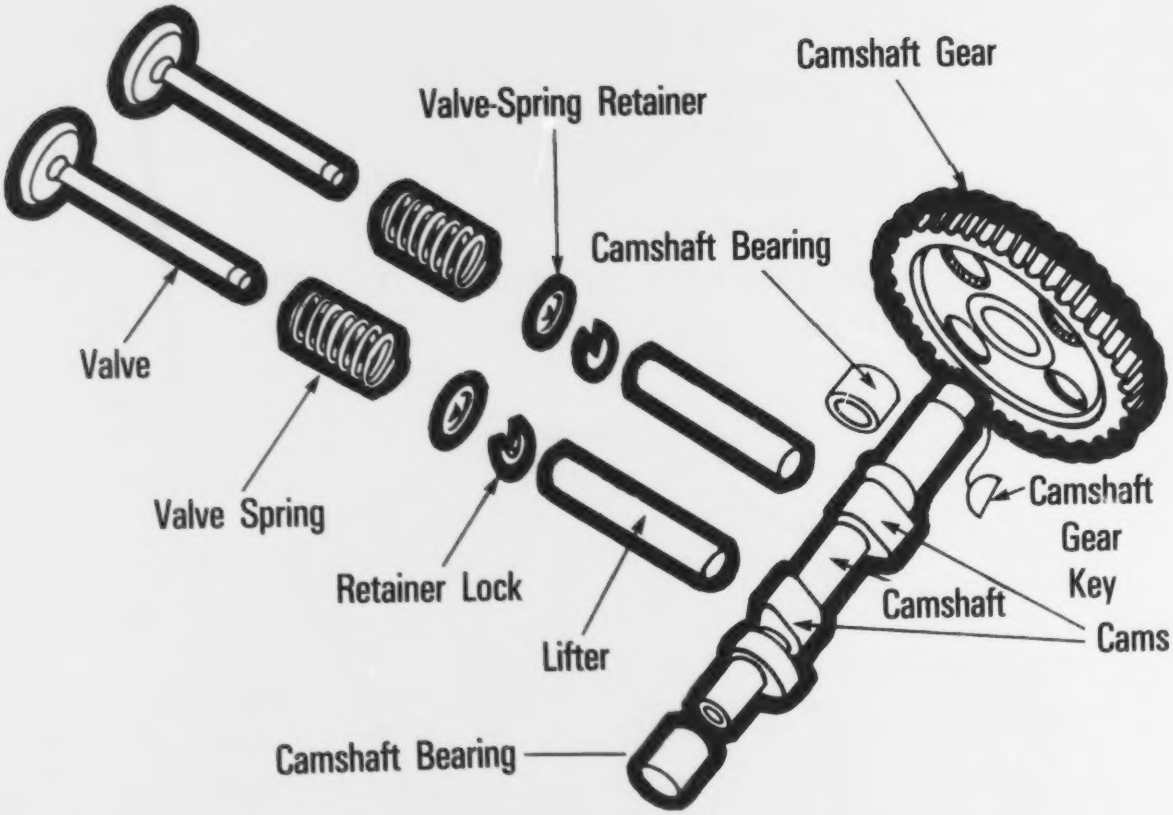
Visual 2.18

Connecting Rod and Crankshaft Components

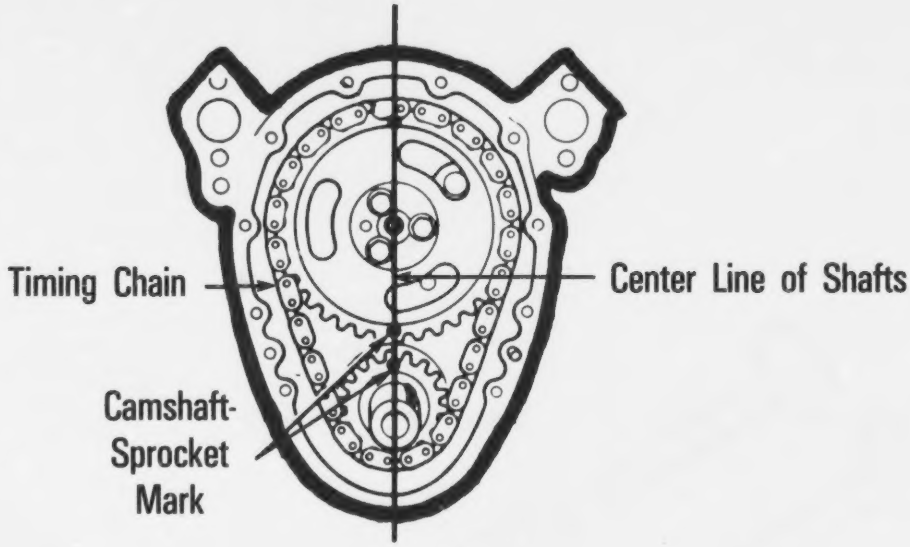

Cylinder
Piston
Connnecting Rod
Crankshaft
Camshaft
Crankshaft
Timing Gears
Rocker Arm
Valve Spring
Valve
Push Rod
Valve
Rocker Arm
Push Rod
Valve Lifter
Camshaft
Cams
Timing Gears

Visual 2.19

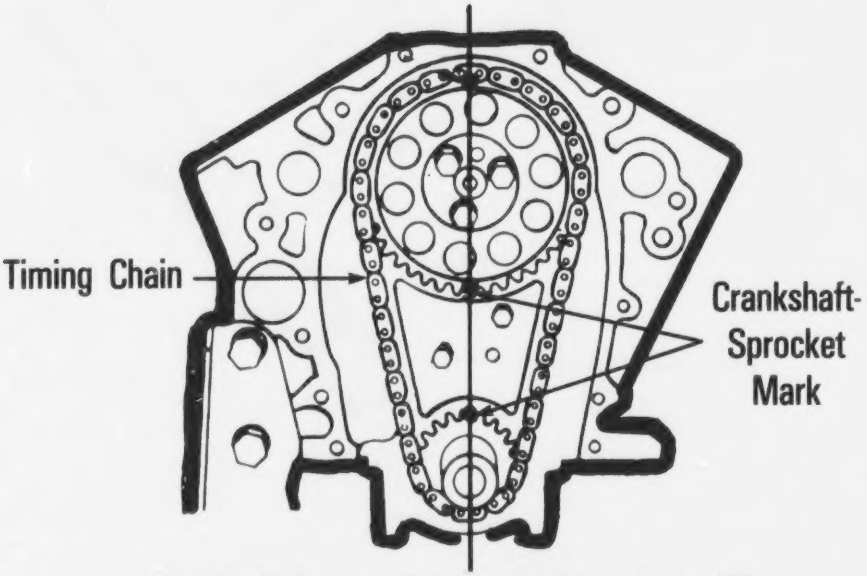
Valves and Camshaft


Camshaft Gear
Valve-Spring Retainer
Camshaft Bearing
Valve
Valve Spring
Retainer Lock
Lifter
Camshaft Gear Key
Camshaft
Cams
Camshaft Bearing

Timing Chain and Sprockets


Timing Chain
Center Line of Shafts
Camshaft-
Sprocket
Mark

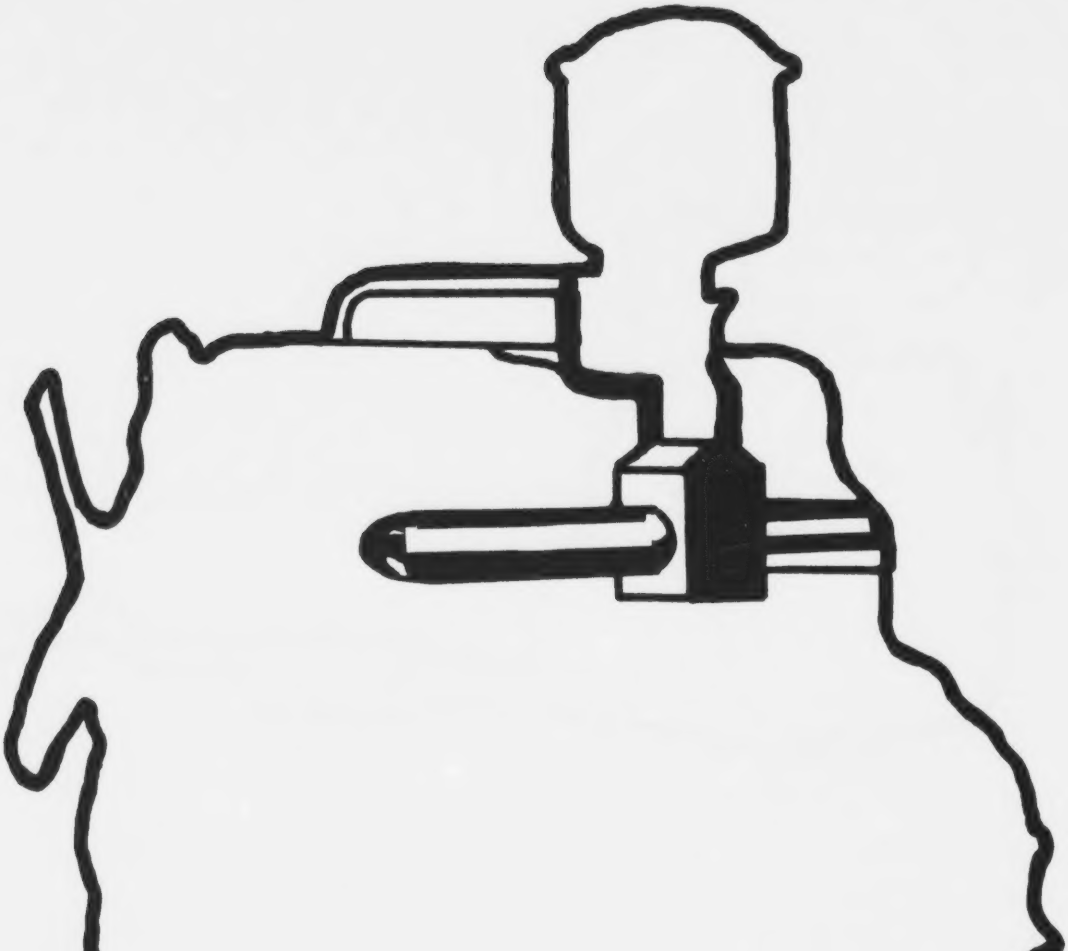
Crankshaft and Camshaft Sprockets With Chain Drive for a Six-Cylinder Engine.


Timing Chain
Crankshaft-
Sprocket
Mark

Crankshaft and Camshaft Sprockets With Chain Drive for a V-8 Engine.

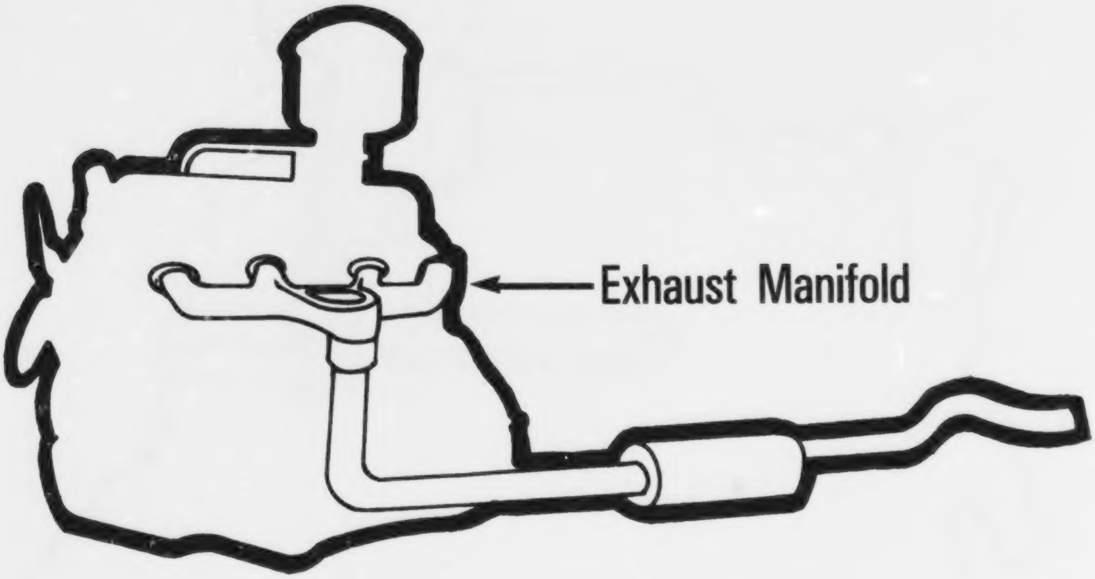
Visual 2.21

Intake Manifold



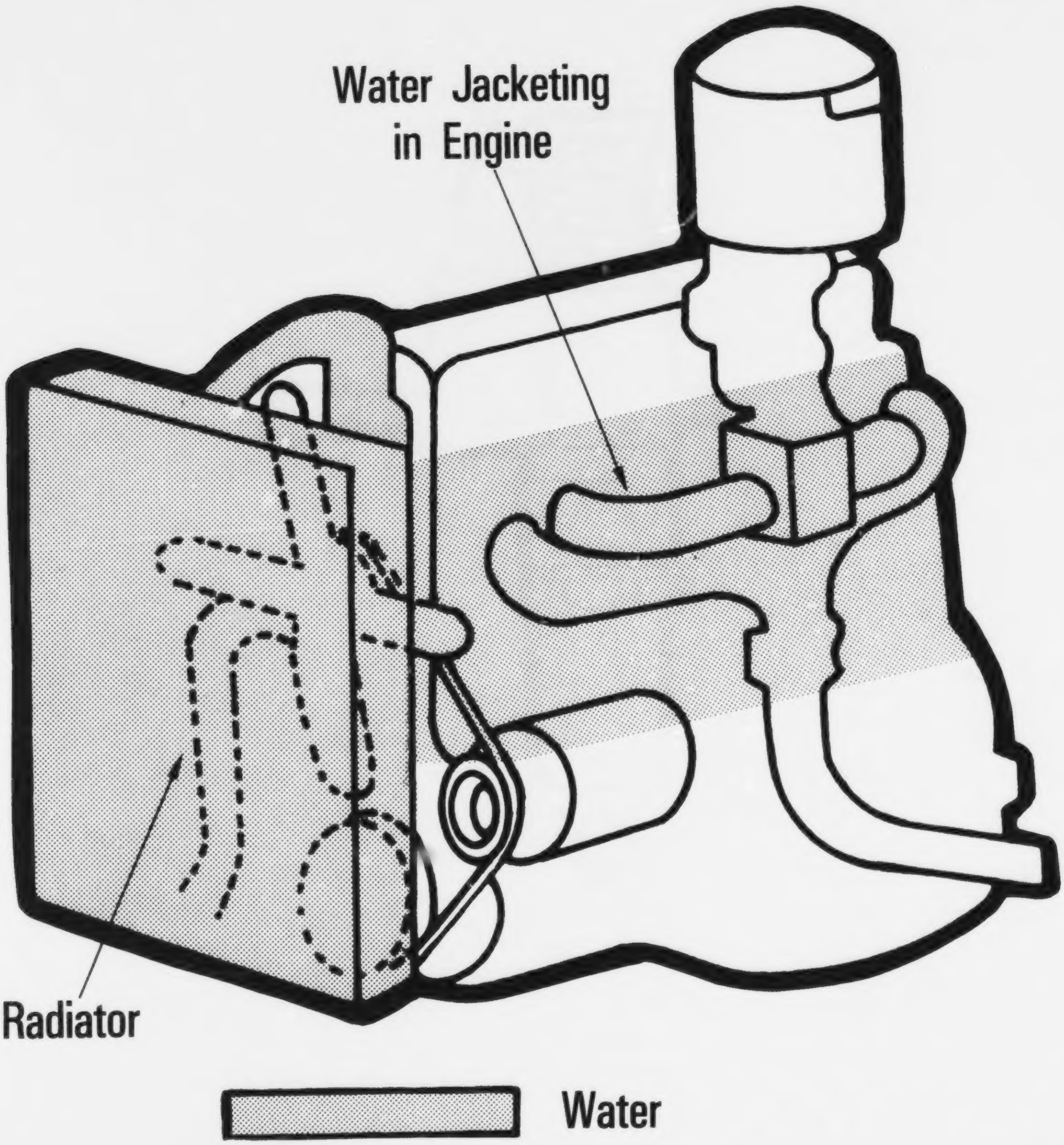
Visual 2.22

Exhaust Manifold


Exhaust Manifold

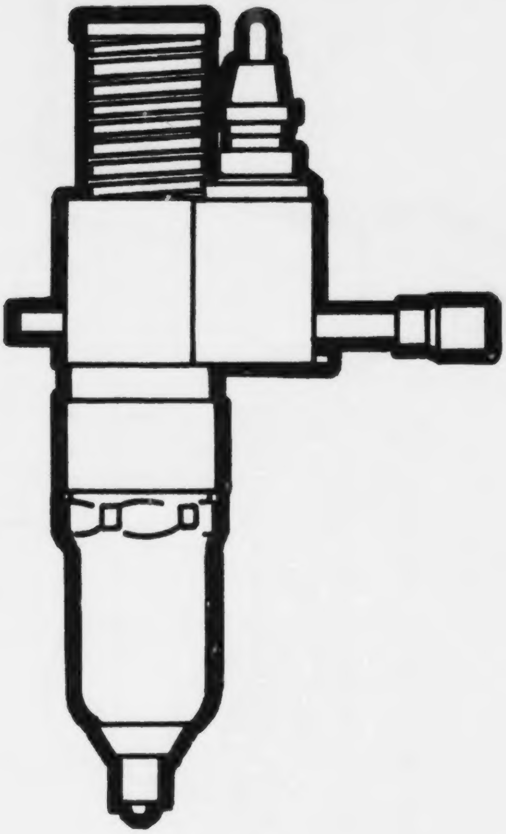
Visual 2.23

Water Jacket


Water Jacketing in Engine
Radiator
Water

Visual 2.24

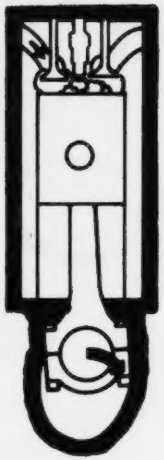
Injectors



Injector

Four-Stroke Cycle

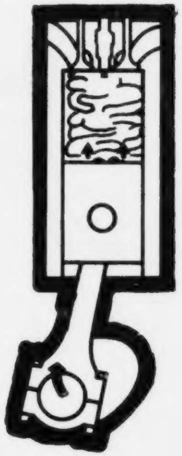
Stroke 1



Intake

Intake Valve Open
Exhaust Valve Closed
Piston Moves Down

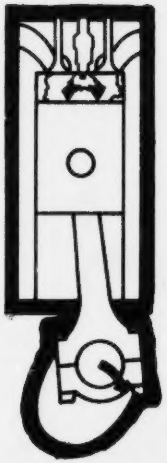
Stroke 2



Compression

Both Valves Closed
Piston Goes Up

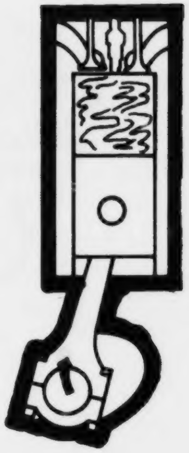
Stroke 3



Power

Both Valves Closed
Piston Being
Pushed Down By
Expanding Gases

Stroke 4

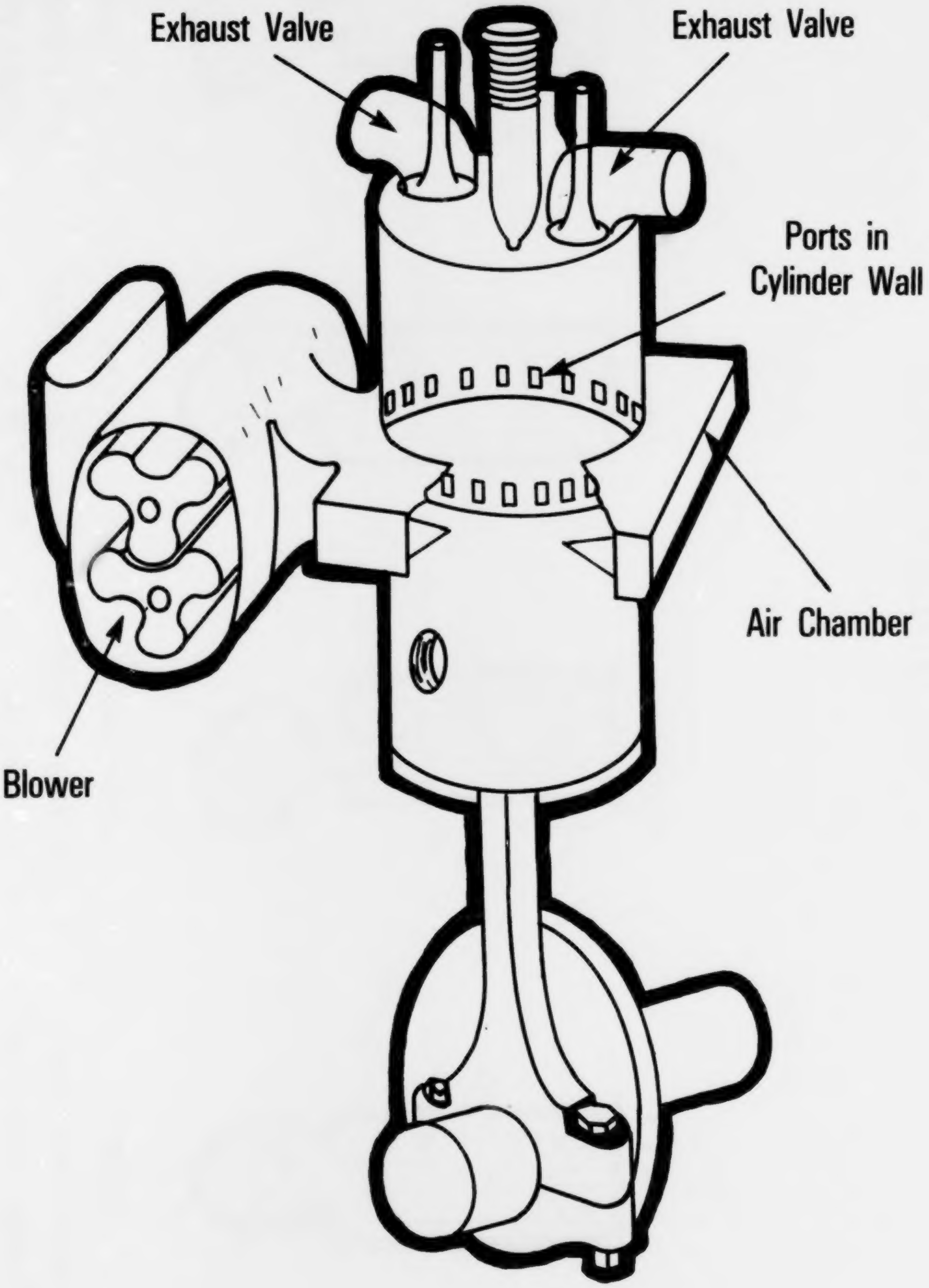


Exhaust

Intake Valve Closed
Exhaust Valve Open
Piston Moves Up

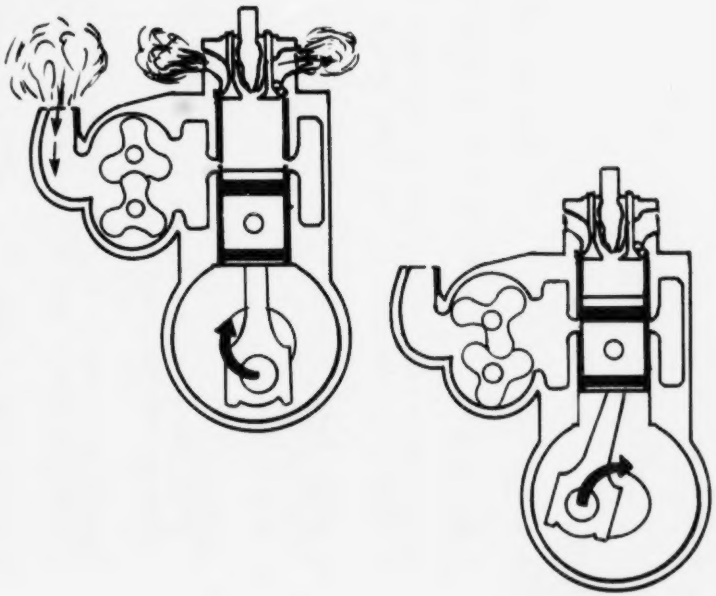
Visual 2.26

A Two-Cycle Engine Cylinder

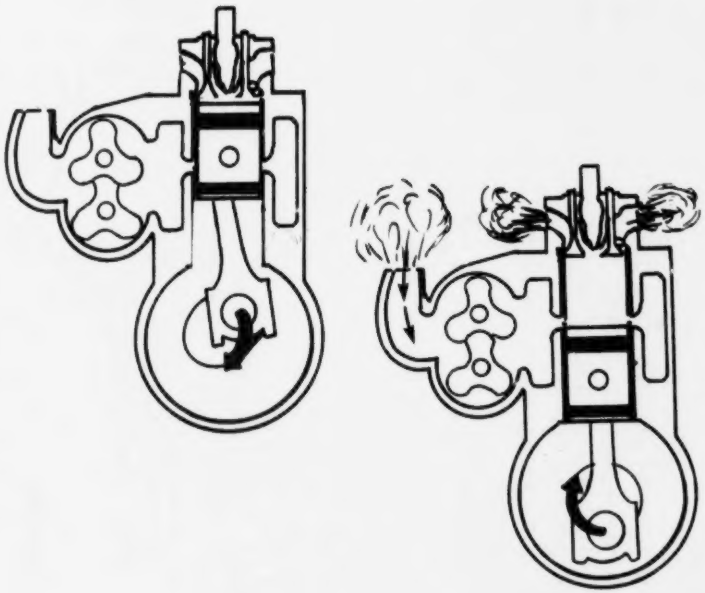

Exhaust Valve
Exhaust Valve
Ports in Cylinder Wall
Air Chamber
Blower

Two-Stroke Cycle

Stroke 1
Intake and Compression



Stroke 2
Power and Exhaust



3. FUEL SYSTEMS (35 minutes)

Introduction

This topic is designed to give students a fundamental knowledge of
- The basic types of diesel engine fuel systems
- Operating principals of major fuel system components
- Types of diesel fuel
- Cost and complexity of modern diesel fuel systems and their relation to
  - Safety
  - Economy

Visual 3.1 Purpose of Diesel Fuel Systems

Purpose

Diesel fuel systems
- Store the fuel
- Remove contaminants (clean)
- Deliver fuel to each cylinder
- Meter, pressurize, atomize and inject into each cylinder
  - In proper sequence
  - With precise timing

Types of Systems

Different engines have different systems to deliver fuel to cylinders
There are four types of systems

Visual 3.2 A Diesel Fuel System

Basic System

Almost all diesel systems involve the following elements

Fuel Tank--A tank in which fuel is stored until it is needed

Fuel Lines--Lines along which the fuel is distributed to the remaining elements in the fuel system

Transer Pump--A pump that draws the fuel from the gas tank and forces it through the fuel lines to the remaining elements of the system

Governor--A device connected to the engine that maintains the fuel pressure when the engine is idling and cuts it off when the engine reaches maximum rpm

Throttle--A device that regulates the pressure of fuel reaching the cylinders, and hence the speed of the engine

Plunger Pump--A pump that meters and supplies fuel to each of the cylinders

Injectors--Devices that receive fuel, atomize it into a fine spray, and inject it into the cylinders for combustion

The three systems to be described differ primarily in the way in which these elements are arranged

Visual 3.3 Multiple Pump System

Multiple Pump System

- Uses individual pump plungers for each cylinder
  - To meter proper amount of fuel
  - To inject fuel into each cylinder
- System operation
  - Transfer pump
    - Draws fuel from tank
    - Delivers fuel to individual plungers
  - Plunger
    - Operates individually to deliver fuel to the cylinder at the right time
    - Measures amount of fuel delivered to cylinder
    - Delivers fuel under high pressure to cylinder
    - Controlled by throttle
  - Fuel lines
    - Deliver fuel from each plunger to each cylinder
    - Check valves prevent return of fuel from fuel lines
  - Injectors
    - Receive fuel at high pressure from fuel line
    - The pressure opens injection valves allowing fuel to pass to cylinder
    - Fuel mixes with air and ignites

Visual 3.4 Unit Injection System

Unit Injector System

- Similar to multiple pump system, except that one pump delivers fuel to all cylinders
  - System operation
    - Transfer pump
      - Draws fuel from tank
      - Delivers fuel through single fuel line directly to injectors
    - Timing Rack
      - Meters fuel for delivery to injector
      - Controls timing of individual injectors
    - Injectors
      - Opened indiviudally by timing rack
      - Spray fuel into cylinder for combustion

Visual 3.5 Distributor System

Distributor System

- Uses a single plunger meters fuel to all cylinders
- A distributor routes fuel to each cylinder

- System Operation
    - Transfer pump
        - Draws fuel from tank
        - Delivers fuel to a metering pump
    - Metering pump
        - Is a single plunger pump
        - Meters fuel for all cylinders
        - Is controlled by throttle to regulate amount of fuel delivered
    - Distributor system
        - Operates in a manner similar to an electrical distributor on a gasoline engine
        - Receives fuel from metering pump
        - Delivers fuel in separate fuel lines to each injector
    - Injectors
        - As fuel reaches injector, pressures causes injector to open
        - Fuel is sprayed into cylinder for combustion
        - Because of distributor, injectors work in sequence

Visual 3.6 Pressure-Time System

Pressure-Time System

- Transfer pump supplies pressure to deliver fuel to cylinders
- Metering occurs in cylinders
- System operation
    - Fuel pump draws fuel from tank and delivers it to cylinders
    - Pressure regulator controls pressure in fuel line
    - Throttle regulates flow to injectors
    - Governor controls idling and maximum rpm
    - Injectors
        - Contain plungers to force fuel into cylinders
        - Metering orifice (small hole) regulates amount of fuel entering cylinder
    - Simplest of the four systems

Components and Functions

Diesel Fuel Oil

Functions

- Mixes with air and burns to provide engine power
- Lubricates fuel system and engine parts

Grades

- Diesel fuel is classified into three grades
    - Numbers 1, 2, and 4 grade
    - The higher the number grade, the more it has been refined

Refining

- Removes impurities
- Lowers heat valve (power)
- Higher grade fuels
- Has fewer impurities
- Slightly less power than same quantitiy of low grade fuel

Properties

- Three of the most important properties in selecting diesel fuel are
  - Distillation range--point at which fuel boils
  - Cetane number
    - Measure of ease with which fuel will ignite
    - The higher the number, the less lag time between
      - When fuel enters cylinder
      - When it burns
    - Cetane numbers range from around 30 to as high as 60
    - Generally, the higher the number, the better the fuel
  - Sulfur content
    - One component of diesel fuel
    - High sulfur content causes
      - Excessive deposit formations
      - Premature wear
      - Exessive sulfur dioxide in exhaust

Selection of Fuel

- Engine speed, load and climate influence seleciton of
  - Distillation range
  - Cetane number
  - Most diesel engines today burn Number 2 grade diesel fuel
  - Number 2 diesel is divided into
    - Summer grades
    - Winter grades
  - The difference is that winter grades have a higher cetane number
  - Quality and cleanliness of fuel is a major concern
  - For the fuel systems to function properly
    - Fuel must contain as few contaminants (water, solid particles) as possible
    - System components must be capable of removing and/or dealing with contaminants that do exist in the fuel
    - Fuel filters, fuel heaters and water separators, deal with these problems (will be discussed later)
  - Water in fuel can destroy injectors, pumps, etc.
  - Diesel fuel burns and lubricates parts, water does neither

Fuel Storage Tanks(s)

- Is a vented fuel storage container
- Most tractor-trailers have two tanks
  - One is on each side of tractor (saddle tanks)
  - Each tank has a shut off valve
  - Valve must be open to get fuel out
- Tanks are connected by a cross-over fuel line (fuel can be used from either tank)
- Most tanks have a drain plug
  - Located in bottom of tank
  - Drains water from fuel
  - Water and condensation settle to bottom of tank

Fuel Heater

- Heats fuel in system
- Several types
  - In tank units--heats fuel while in tank
  - In line units--heats fuel on its trip from tank to injectors
  - Filter units--heats filter element and fuel in element before moving it to injectors
  - Two or all three types can be used in one system
- As temperatures fall below zero, wax crystals form in diesel fuel
  - Wax crystals clog
    - Filters
    - Injectors
    - Fuel lines
  - The result of "waxing" can be
    - Failure of engine to start
    - Shutting down of engine on the road
    - Expensive engine damage
  - Fuel heaters
    - Keep crystals from forming
    - Allow vehicle to operate in subfreezing weather

Water Separator

- Removes water from diesel fuel
- Fuel containing water
  - Can shut down engine
  - Does not lubricate adequately
  - Can cause damage
    - Rust
    - Corrosion
    - Excessive wear
  - Engine parts effected are
    - Pistons
    - Piston rings
    - Fuel pump(s)
    - Injectors
- Water Separators
  - Spin fuel at high rates of speed
  - Because water is heavier than diesel fuel
    - It is thrown out of fuel
    - Collects at bottom of separator
    - Is drained as it accumulates
  - Water separators may be combined with fuel filters and fuel heaters in a single unit

Visual 3.7 Filter Types

Fuel Filters

- Designed to trap and remove from fuel
  - Dirt
  - Wax
  - Gums
  - Resins
  - Other solid particles

- Contaminants are removed before they reach pump(s) and injector(s)
- Most fuel systems have two types of filters

Visual 3.8 Primary and Secondary Filters

Primary Filters

- Usually located between fuel tank and transfer pump
- Provide a rough screen to take out larger particles
  - Remove waxes, gums, resins
  - Suction from fuel pump not strong enough to allow fuel to flow through a fine screen
  - Protect the fuel pump
  - Extends life of secondary filter

Secondary Filter

- Usually located betwen transfer pump and injectors

Purpose

- Removes fine particles from fuel
- Protects injectors
- Employs a fine screen
  - Pressure from transfer pump adequate to force fuel through a fine screen
  - Primary filter screens out heavier particles
  - Small particles could damage or clog injectors
  - Are very sensitive to contaminants
  - Plug up very easily

Additional Filters

- Some systems add a third or fourth filter to system
- Place them between secondary filters and injectors
- Provide added filtration

Fuel Lines

- Transfers fuel from tank to injectors and back again
- Construction
  - Small diameter hoses
  - Metal tubing (e.g., copper)

Two Types

Intake Lines

- Carries fuel from tank to injectors

Return Lines

- Pumps ordinarily furnish more fuel to the injectors than is needed
- Return fuel lines cary unused fuel from injectors back to tank

Visual 3.9 Pumps

Pumps

Two types

Transfer Pump

- Pumps fuel from tanks to rest of fuel system
- Is driven by gears connected to the engine
- Corresponds to "fuel pump" in automobile

Plunger Pump

- Plunger pumps meter and delivers fuel to injectors
- In some systems, the plunger pumps are located next to or within the injectors (unit injectors or time-pressure system)
- In other systems, pumps are located away from injectors (multiple pump system and distributor system)

Visual 3.10 Timing Devices

Timing Devices

- Act like distributor in a gasoline engine
- Time injection of fuel into cylinders so that they "fire" (spray fuel) in a designated order

Timing Racks

- Control the action of
  - Plungers (multiple pump system)
  - Injectors (unit injection system)
- Gears or cams determine order of operation

Rotary Devices (distributor system)

- Operate like gasoline engine distributor
- Disc rotates
- Fuel line connectors arranged in circular pattern
- As disc revolves, fuel is delivered to fuel lines in sequence
- Routes fuel to injectors in sequence

Visual 3.11 Cutaway of Injector

Injectors

- Is simply a piston type pump which forces a small amount of fuel under high pressure into the cylinder
- Physical make up of injectors will vary depending upon type of fuel system

- Unit injector, pressure-time systems
  - Injectors contain
    - Plunger pump--fits closely in a cylinder inside injector
    - Spray nozzle--located at end of injector
  - Injector opertion
    - Plunger slides up and down (piston action) inside cylinder
    - Fuel enters through port in side wall of cylinder (plunger at top)
    - Plunger
      - Pushes down
      - Closes fuel port
      - Squeezes fuel
      - Sprays fuel into cylinder
- Multiple pump and distributor systems
  - Injectors contain only spray nozzle
  - Plunger pump is located outside injector
  - Injector operation
    - Plunger pump force fuel into injector
    - Pressured fuel forces injector valve open
    - Fuel is sprayed into cylinders
- Spray nozzle contains very tiny holes (smaller than tip of pin)
- Fuel is
  - Forced out of holes under very high pressure
  - Split up into very fine particles (atomized)
- This results in
  - Fog-like mist, mixing with compressed air in cylinders
  - Fuel being burned rapidly and completely

Accelerator Pedal and Hand Throttle

- Devices controlled by driver which
  - Increases or decreases amount of fuel injected into cylinders
  - Allows driver to regulate speed of engine
  - Consists of
    - Shaft placed in fuel line
    - Hole in shaft permits fuel to flow
    - Alignment of hole regulates pressure of fuel in line
    - Pressure regulates amount of fuel and speed of engine

Locating and Recognizing Problems

Visual Inspection

- A critical part of any vehicle inspection is checking the fuel system for
  - Visible leaks in the system
  - Fuel tanks not securely mounted
  - Fuel tank caps missing, improperly fitting or defective or missing gaskets
- When any of these situations are present, the vehicle should not be operated until the condition is corrected

Keeping Fuel Clean

Care must be taken to see to it that fuel and fuel system is kept immaculately clean
  Contamination will quickly cause severe damage and/or cause engine to stop
    - Clean surface of tank and tank cap before refueling
    - Take care to prevent any foreign material from entering the tanks during refueling
    - Make sure tank vents (usually located in tank caps) are free of debris and working properly
    - Keep tanks topped off in cold weather to minimize condensation and build up of water in tanks
    - Open petcocks at bottom of tanks and drain off the accumulated water at least once per week

Engine Failure

If, in cold weather, the engine fails to start or suddenly stops while driving, check

Fuel Supply--Have tanks run out of fuel?

Filters--Is fuel passing through the filters?
- May be plugged with wax crystals
- Water in filter may have frozen

If fuel tanks have run dry
- May be necessary to "bleed the air" from fuel system
- Do not attempt unless
  - Properly trained
  - Assisted by a qualified technician
- Check operators manual for details

If filters become plugged
- Replace filter elements
- Attempt only if properly instructed

Recap

Diesel fuel systems are extremely complex and expensive, they
- Should never be touched or tampered with
- High pressures in the lines can cause
  - Serious personal injury
  - Damage to engine

Clean, water free, high quality fuel is absolutely essential for
- Maximum fuel economy
- Prolonged engine life

Water in diesel fuel system can quickly cause extremely serious damage to very expensive components

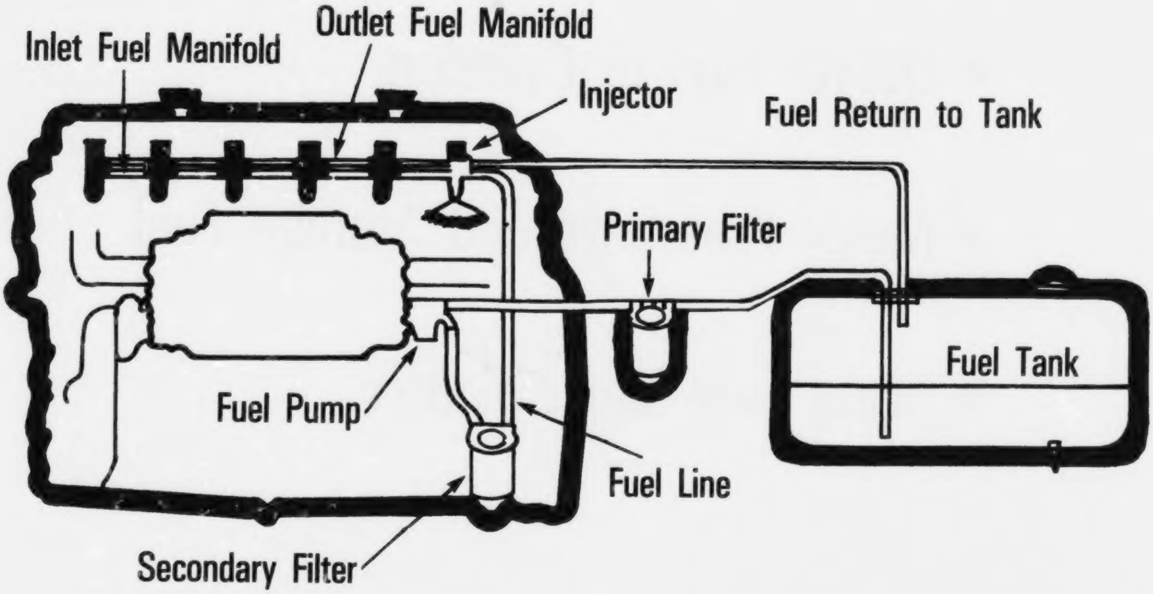
Fuel quality fluctuates widely according to supply and demand
- Always purchase fuel from "reliable" fuel suppliers
- Make sure filters, heaters, and water separators are kept serviced

Purpose of Diesel Fuel Systems

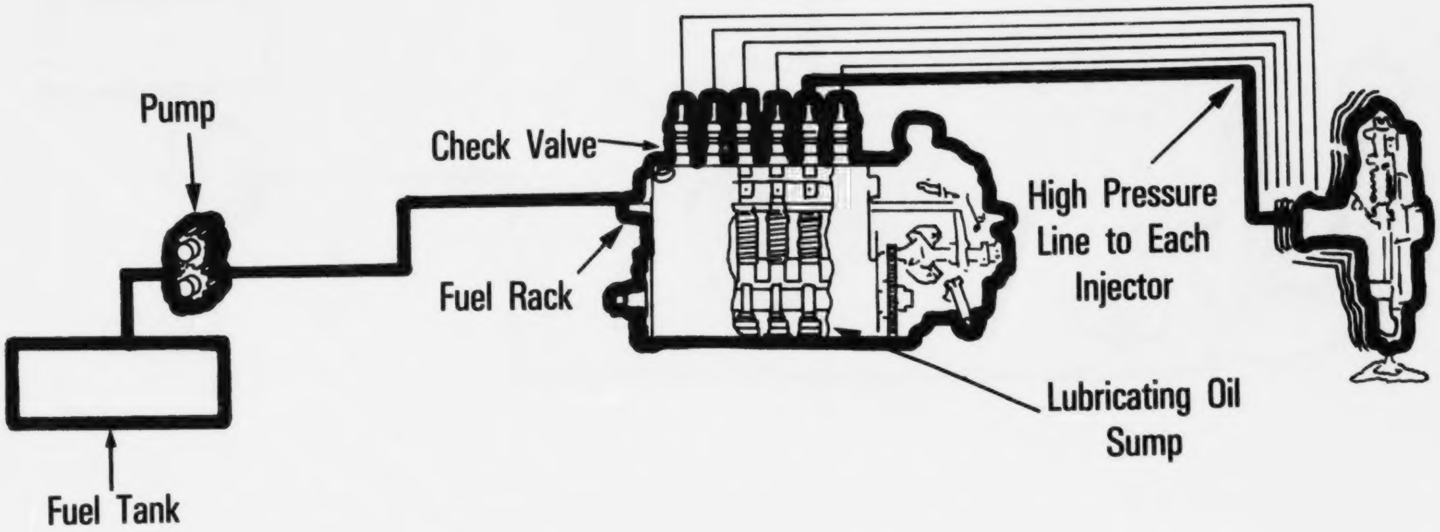
- Store Fuel
- Remove Contamination
- Deliver Fuel to Cylinders
- Meter Pressurize and Atomize Fuel
- Inject Fuel Into Cylinders

Visual 3.2

Diesel Fuel System

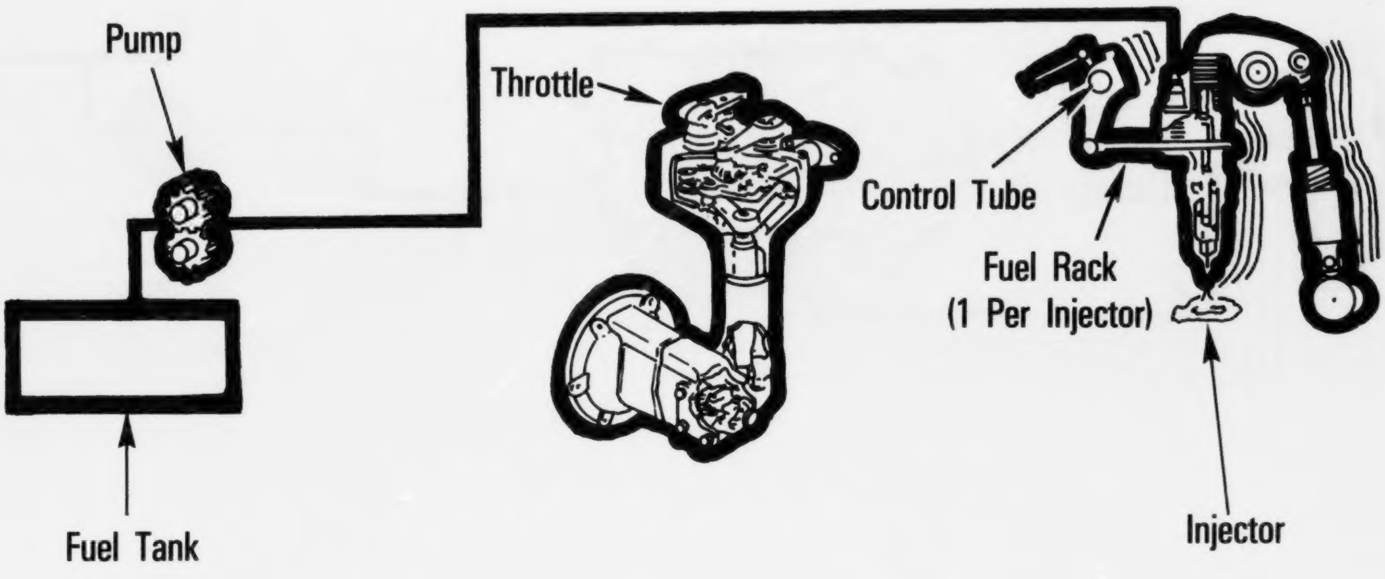

Inlet Fuel Manifold
Outlet Fuel Manifold
Injector
Fuel Return to Tank
Primary Filter
Fuel Tank
Fuel Pump
Fuel Line
Secondary Filter

Multiple Pump System

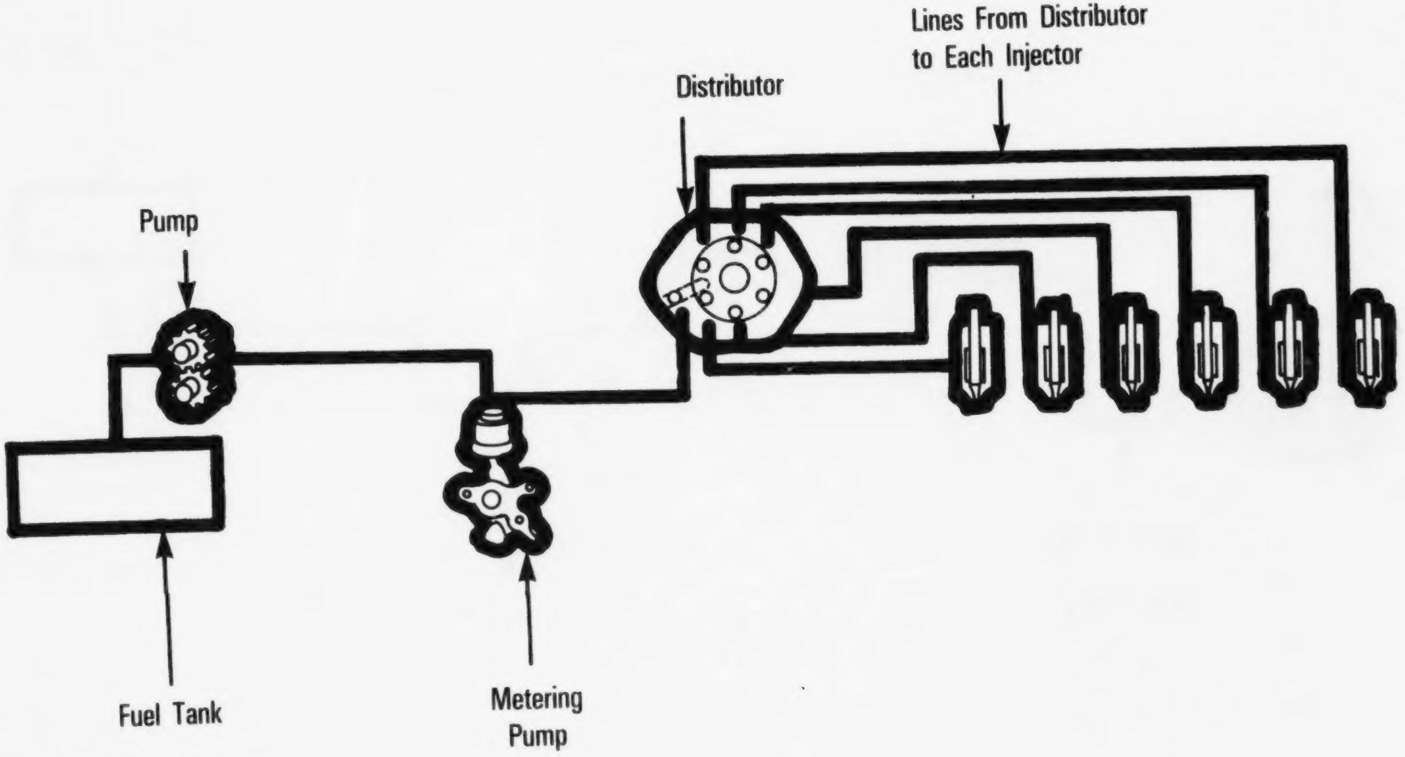

Pump
Check Valve
Fuel Rack
High Pressure Line to Each Injector
Lubricating Oil Sump
Fuel Tank

Visual 3.4

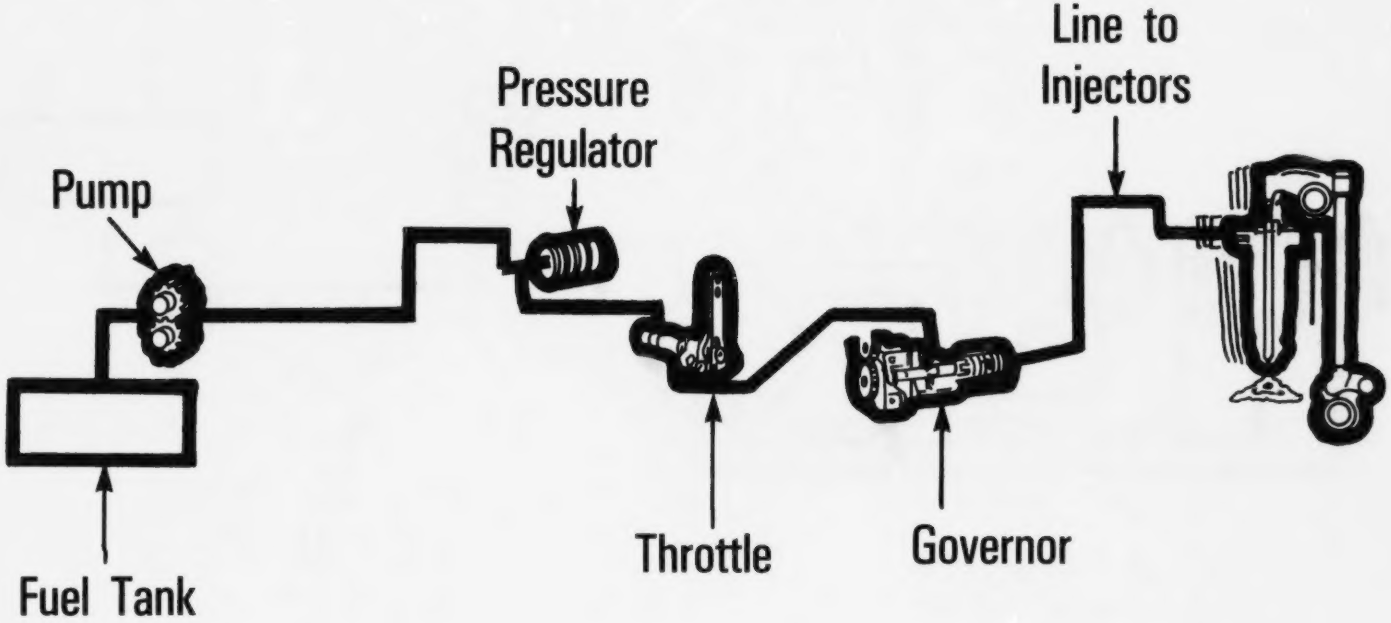
Unit Injection System


Pump
Throttle
Control Tube
Fuel Rack
(1 Per Injector)
Fuel Tank
Injector

Distributor System

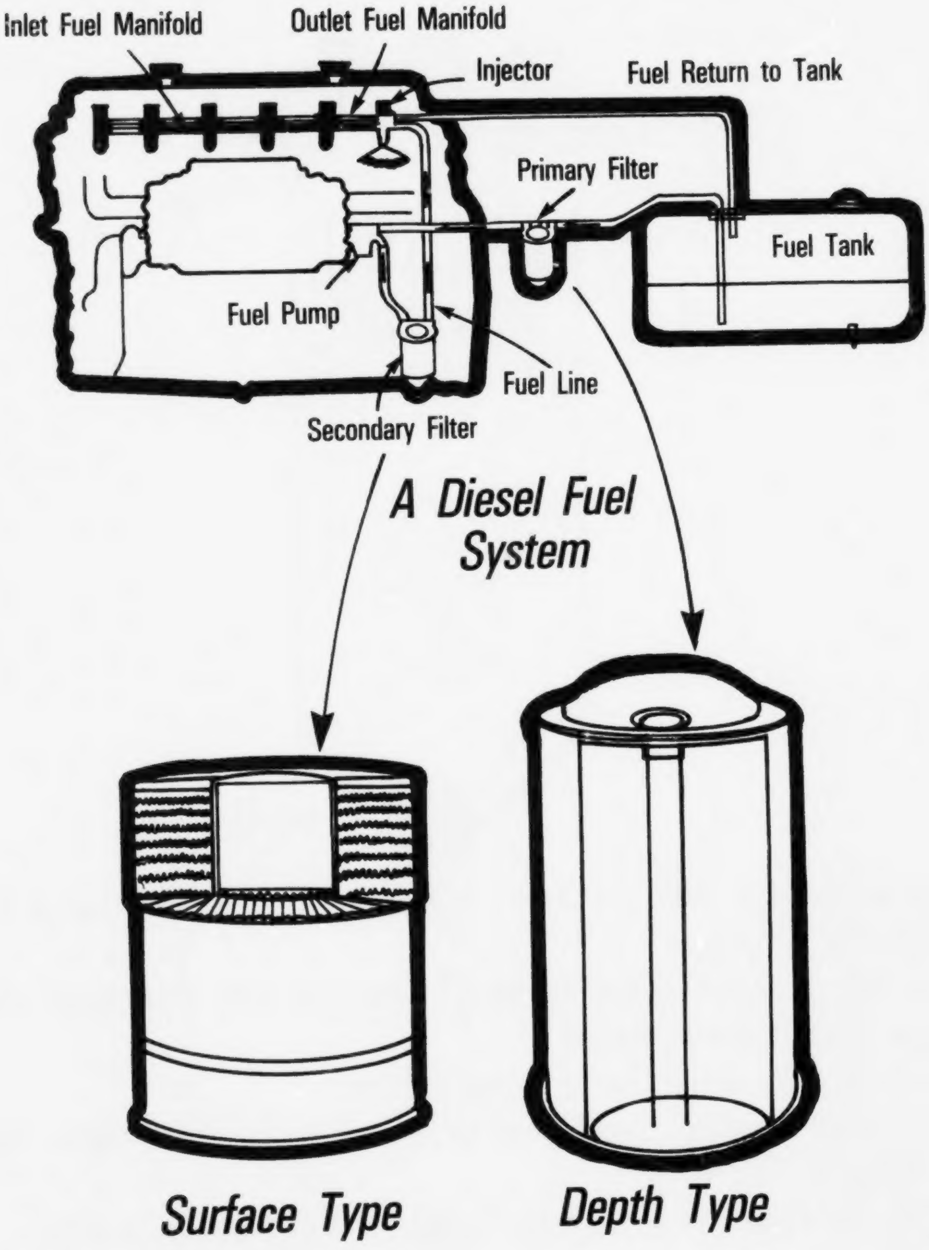

Lines From Distributor to Each Injector
Distributor
Pump
Fuel Tank
Metering Pump

Pressure-Time System


Pump
Pressure
Regulator
Line to
Injectors
Fuel Tank
Throttle
Governor

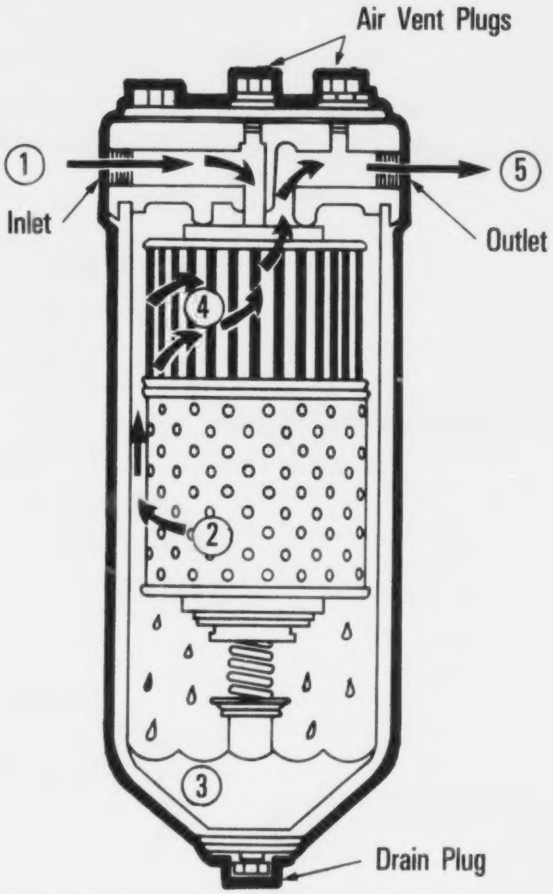
Visual 3.7

Filter Types


Inlet Fuel Manifold
Outlet Fuel Manifold
Injector
Fuel Return to Tank
Primary Filter
Fuel Tank
Fuel Pump
Fuel Line
Secondary Filter
A Diesel Fuel System
Surface Type
Depth Type

Visual 3.8

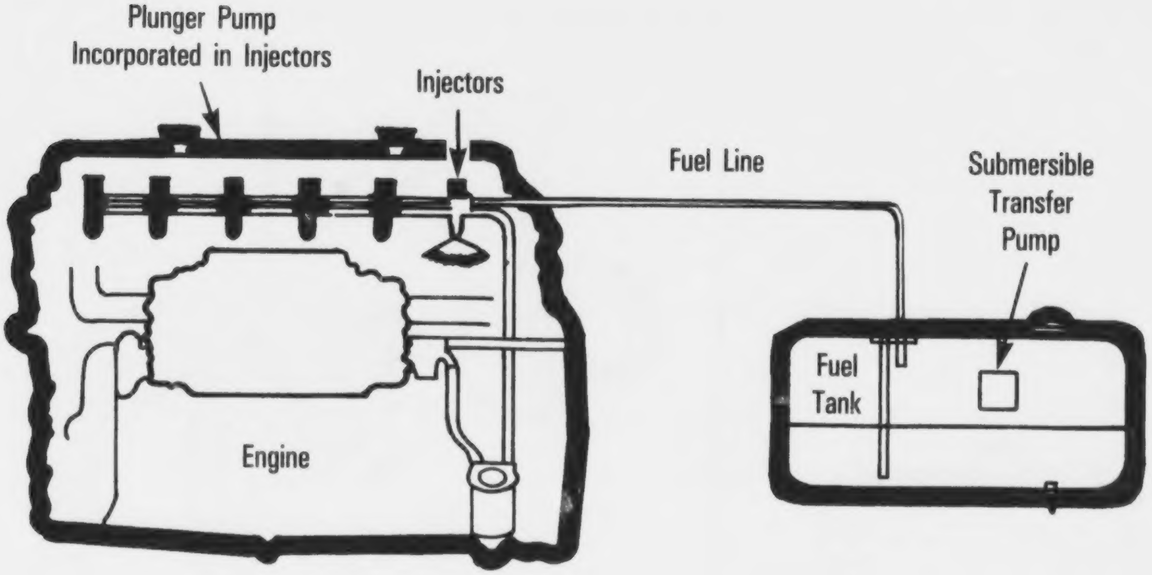
Primary and Secondary Filters



1. Fuel Enters Filter Inlet and Runs Through Center Tube to Inside of Coalescer Section of Cartridge.
2. Dirt, Rust, and Solids Are Filtered Out. Water in Fuel Is Coalesced Forming Large Droplets for Separation.
3. Water Droplets Settle Out to Sump of Filter.
4. Fuel Enters Separator Section and Is Filtered Second Time. Water Drops Are Rejected by This Media.
5. Clean Fuel Then Passes Through Center Tube of Cartridge and Out Filter Outlet.

Visual 3.9

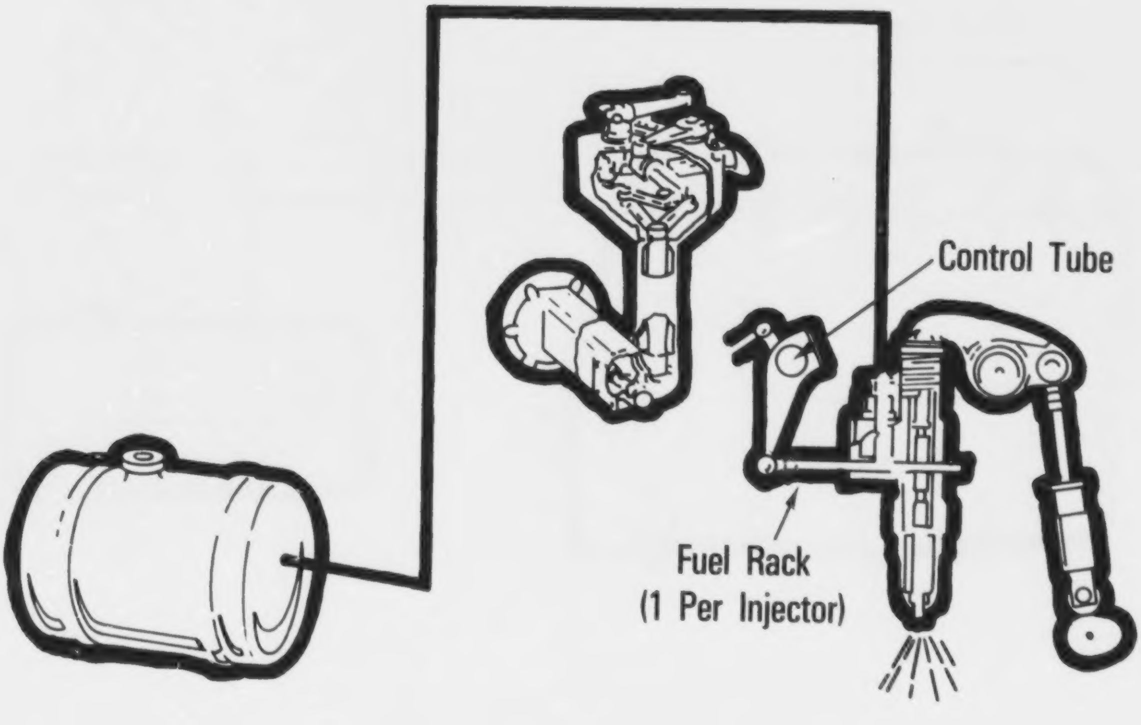
Pumps


Plunger Pump
Incorporated in Injectors
Injectors
Fuel Line
Submersible
Transfer
Pump
Fuel
Tank
Engine

Visual 3.10

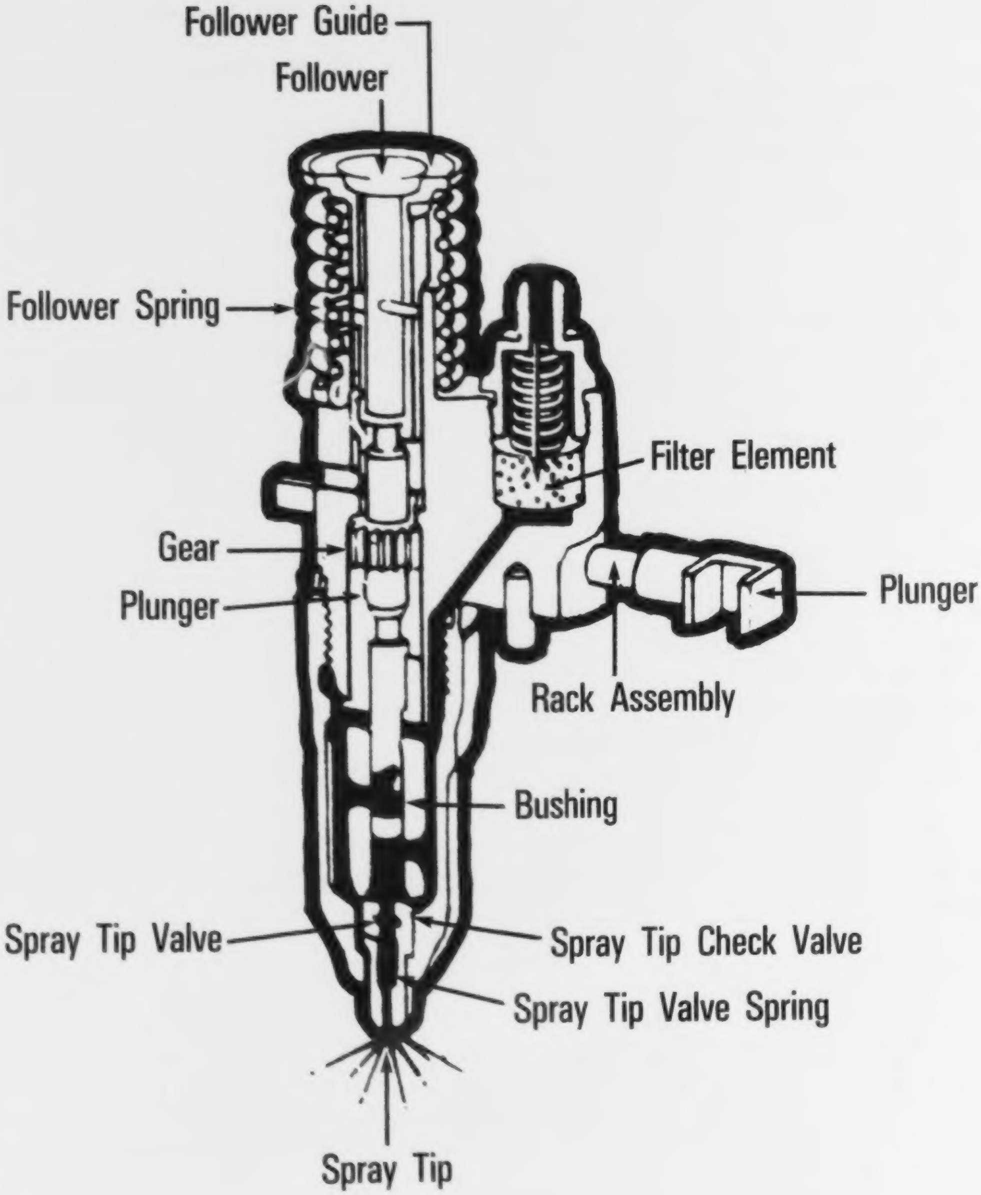
Timing Rack & Injectors

uel Transfer Gear Pump Moves Fuel From Tank to Injectors Under Low Pressure Through a Single Fuel Line. Governor and Throttle (at Right) Control Fuel Metering in Injectors Through Linkages, Control Tube Levers and Individual Fuel Racks.


Control Tube
Fuel Rack
(1 Per Injector)

Visual 3.11

Cutaway of an Injector


Follower Guide
Follower
Follower Spring
Filter Element
Gear
Plunger
Plunger
Rack Assembly
Bushing
Spray Tip Valve
Spray Tip Check Valve
Spray Tip Valve Spring
Spray Tip

4. AIR INTAKE AND EXHAUST SYSTEMS (25 minutes)

Introduction

This topic is intended to give students a fundamental knowledge of
- Various types of engine air intake systems and components
- Operating principals of turbochargers and superchargers
- Various types of engine exhaust systems
- The effect of proper design, operation and maintenance of intake and exhaust systems upon
  - Engine longevity
  - Maximum engine efficiency

Air Intake System

Purpose

Supplies engine with massive amounts of clean dry air which
- Provides sufficient oxygen for maximum combustion of fuel
- More air = more oxygen = more complete fuel combustion = more horsepower

Types of Systems

Visual 4.1 Types of Systems

Types of Systems

There are three basic air intake systems
- Naturally aspirated
- Turbocharged
- Supercharged

All three draw air form either
- Under the hood
- Outside the engine compartment
  - More common
  - Provides better source of clean air

The difference between the three is the way they draw air into combustion chamber

Naturally Aspirated

Four-Cycle Engine
- Piston goes down
- Air pressure in cylinder decreases
- Outside atmospheric pressure forces air in
- Air is drawn into cylinder through ports uncovered by the intake valves

Two-Cycle Engine
- Air must get into cylinders in a very short span of time without help of pumping action of piston

- A blower is utilized
  - Blower is gear driven
  - Forces air into cylinder through holes in cylinder wall

Turbocharger

- Can be used with both four- and two-cycle engines
- Utilizes an air pump to force a greater air flow into engine cyliners
- Air pump driven by exhaust gases

Supercharger

- Can be used with both four-and two-cycle engines
  - Also uses an air pump to force heavier air flow into cylinders
- Air pump driven mechanically by crankshaft

Components and Functions

Visual 4.2 Air Intake System

Intake Pipe

- Carries outside air to filtering system
- Three locations

- Behind cab
  - Usually found in "cab-over" tractors
  - Also called a "snorkel"
  - Extends upward at rear corner and top of cab

- Side of hood
  - Usually found in conventional tractors
  - Also called a "scoop" or "inlet tube"
  - It is a scoop cut into side of tractor hood

- Fender mount
  - Usually found in conventional tractors
  - Also called an "inlet tube"
  - Mounted between right front fender and cab door

Rain Cap

- Also called "rain bonnet" or "inlet cap"
- Fits on end of intake pipe
- Reduces amount of moisture entering system

Filters

- Diesel engines require massive amounts of dry clean air to function
- Air filters:
  - Remove dust, dirt, lint, water, etc., from air
  - Allows only dry clean air to reach cylinders

- Some vehicles are equipped with both primary and secondary filters
    - Primary elements--remove coarse particles
    - Secondary elements--remove finer dust particles

Basic Types

There are two types of air filters:

Visual 4.3 Oil Bath Filter

Wet (Oil Bath) Filters

- Consists of
    - Oil reservoir
    - Fiber or metal mesh filter
- Air is
    - Forced down through filter element
    - Deflected off oil reservoir at bottom of housing
    - Forced back up through mesh filter
    - Oil splashes over filter
    - Traps dirt particles
- Operates efficiently only when engine is turning over fast
    - Must suck a lot of air into the cleaner
    - Need to keep plenty of oil splashing over the filter elements
- Should not idle engine for prolonged periods of time
- If forced to stop in a dust storm:
    - Turn off engine or,
    - Keep engine operating at about 1,000 rpms
- Important not to over rev engine
    - Air speed becomes too great
    - Oil may be carried into the engine

Visual 4.4 Dry Air Filter

Dry (Paper Cartridge) Filter

- Consists of a specially treated resin coated paper cartridge
- Air is forced through paper element trapping dirt particles
- Paper is pleated to provide large surface in small space
- Some engines have a centrifugal pre-cleaner
    - Mounted where air enters the filter element
    - A set of vanes caused the air to swirl
    - "Spins" heavier dirt particles out of the air before it enters the filter
    - Some engines use a two-stage filter
        - Two filters placed one after the other
            - Both are generally dry filters
            - Used where air is unusally dirty, e.g., desert, offhighway operations

Water Traps

- Traps are built into the better air filters
- Eliminates moisture in air so that only dry air reaches cylinders

Air Filter Restriction Gauge and Indicator

- Allows visual checking of air filter element to determine need for servicing or replacement
- Two different devices

Restriction Gauge

- Located in cab
- Measures "inches of water" in filtering system
- Gauge indicates to driver when filter needs servicing

Restriction Indicator

- Located either on
  - Air Cleaner housing or,
  - Air inlet manifold
- Device warns driver that filter element is
  - Dirty
  - Needs servicing
- A red ring will appear in middle of indicator when servicing is required

Visual 4.5 Intake Manifold and Valves

Intake Manifold

- Intake manifold is an assembly of tubes through which air flows from filtering system to cylinders

Intake Valves

- Covers opening(s) at top of cylinders
- Lets filtered air into cylinder (four-cycle engine)
- Operation was described under "engines"

Visual 4.6 Turbocharger

Turbocharger

- Is an air pump designed to increase flow of air into the combustion chamber
- Consists of a
  - Turbine
  - Compressor
- Powered by exhaust gases

Operation

- Gases turn turbine wheel and shaft
- Shaft rotates blades of compressor
- Blades draw air through filtering system into compressor
- Air is compressed and pushed through intake manifold into cylinder

Purpose

- Increases power
  - Forces more air into cylinders
  - Increases combustion

  - Reduces engine wear
    - Horsepower can be delivered at lower rpm levels results in
    - Less engine wear
    - Fewer maintenance problems and costs
    - Longer engine life
  - Reduces noise
    - Exhaust gases are smoothed out as they pass through turbocharger
    - Fuel is burned more efficiently
      - More uniform pressure is created
      - High engine noise levels caused by sudden peaks in cylinder pressure are lowered
  - Reduces ignition delay
    - Time between injection of fuel and engine combustion is delayed
    - Piston chatter occurring during delay is reduced
  - Increases fuel efficiency
    - Improved combustion efficiency (more oxygen in cylinder)
    - Decreases amount of fuel required
      - Fuel mileage is increased
      - Fuel costs are lowered
- Operating requirements
  - Engine start-up
    - Turbochargers are lubricated with engine oil
    - After engine has been started, there is a short period of time before oil reaches turbocharger (lag time)
    - Driver must let engine idle several minutes after start-up
      - Allows oil to reach turbo (before engine is run at high speeds)
      - Prevents turbo damage
  - Engine shut-down
    - Turbocharger generates enormous heat
    - Must be allowed to cool
    - Driver must let engine idle several minutes before shutting it off
    - Allows air intake to cool turbocharger
  - Maintenance
    - Turbocharger operates up to 90,000 rpm
    - Generates heat up to 1,400°
    - Requires
      - Unrestricted supply of air
      - Ample lubricant
    - Inadequate maintenance can cause turbocharger units to melt, burn out

Two-Stage Turbochargers

- Two turbochargers placed in series
  - First turbocharger compresses air at low pressure
  - Second turbocharger receives air from first turbocharger and compresses it more
- Two turbochargers can achieve approximately 50 percent greater pressure than single turbochargers

Automatic Turbocharger Controls

- Regulates amount of air pressure compression
- Senses the air pressure coming out of the turbocharger

        Air pressure reaches the desired level
        Valve opens to allow some exhaust gas to bypass the turbocharger turbine
    Turbine slows down
    Pressure remains at desired level

Visual 4.7 Supercharger

Supercharger

- Is an air pump designed to increase flow of air into combustion chambers
    - Operates in the same manner as turbocharger
    - Is mechanically powered by crankshaft using belt, gears or chains
    - Load on crankshaft robs engine of power normally available to wheels
    - Superchargers are giving way to turbochargers in newer engines
    - Turbocharger uses exhaust gases for power
        - Exhaust gases are a by-product of combustion
        - Does not draw power away from the wheels

Blower

- Is a belt driven air pump, utilized by two-cycle engines
    - Located outside engine
    - Forces air through holes cut in cylinder wall
- In four-cycle engines, intake and exhaust strokes act as an air pump
- In two-cycle engines
    - Intake and exhaust strokes are eliminated
    - Need for blower is created

After Cooler

- Also called "intercooler" or "thermal cooler"

Function

- Cools intake air after it leaves turbocharger
    - Turbocharger compression raises air temperature to around 325°F
    - After cooler reduces temperature to below 200°F
    - Cooler denser air permits
        - Better combustion
        - Improved engine performance
        - Increased engine life

Operation

- Two types of after coolers
    - Air-to-air heat exchangers
        - Compressed air from turbocharger circulated through a radiator mounted in front of cooling system radiator
        - Air from cooling system fan cools compressed air
        - Cooler compressed air enters cylinder
    - Air-to-water exchangers
        - Water from engine circulates through small radiator
        - Compressed air passes across radiator
        - Heat from compressed air is absorbed by water in radiator
        - Cooler air passed directly to cylinders

Glow Plugs

Initial start in cold weather may require warming intake air prior to starting

Glow plugs inserted into air intake system warms the air used to start engine

Exhaust System

The system's purpose is twofold:

Discharges combustion by products from engine

Suppresses engine exhaust noise

Components and Functions

Visual 4.8 Exhaust System

Exhaust Valve

Covers opening(s) at top of cylinder

When open, allows exhaust gases to escape from cylinder

- Four-cycle engines--usually hve one exhaust valve per cylinder
- Two-cycle engines--usually have two per cylinder

Operation of exhaust valves described earlier under "Engines"

Exhaust Manifold

Attaches to side of cylinder head

Is an assembly of tubes through which exhaust gases exit cylinder block

Exhaust Pipe

Attaches to exhaust manifold

Carries gases from manifold to muffler

Split System

- Some "v" type engines have two exhaust pipes
- One pipe provided for each row of cylinders

Single System

- Some "v" type engines have only one exhaust pipe
- A cross-over pipe connects exhaust manifolds to a single exhaust pipe

Muffler

Attaches to exhaust pipe

Has a series of passages through which exhaust gases must flow

Softens or muffles exhaust noise

Those systems with two exhaust pipes will have two mufflers, one for each pipe

Tail Pipe

- Attaches to other end of muffler
- Carries exhaust gases from muffler
- Expels gases into atmosphere

Rain Cap

- Attaches to end of tail pipe (vertical system)
- Covers opening, preventing moisture from getting into exhaust stack
- Exhaust gases force cap open when engine is running
- When engine is stopped, cap automatically closes

Pyrometer

A pyrometer is a gauge which measures exhaust temperatures

Purpose

- Exhaust gases are very hot
- Excessive heat can result in burned valves, pistons and cylinder liners
- Excessive exhaust heat can occur as the result of
  - Too much fuel entering the cylinders
  - Faulty injectors
  - Clogged air filters
  - Lugging engine
  - High altitude operation
- By monitoring exhaust temperatures, a driver is able to recognize when overheating is taking place, allowing him to
  - Throttle down
  - Downshift

Operation

- A temperature sensing device (thermocouple) senses exhaust temperature
  - Sensors usually installed in turbocharger (driven by exhaust gases)
  - Sensor sends electrical signals to the pyrometer gauge in the dashboard
  - Some systems sound an alarm when exhaust temperatures reach dangerous level
- Driver can reduce temperature by downshifting
- Some pyrometers are connected to fuel supply
  - Switch is activated when exhaust temperatures reach dangerous level (e.g., 950°)
  - Switch diverts fuel from fuel system
    - Engine burns less fuel
    - Engine power drops
    - Exhaust temperature drops

Arrangement of Exhaust Components

Exhaust components can be arranged vertically or horizontally

Vertical Arrangement

- In a vertical system, exhaust pipe(s), muffler(s), tail pipe(s) and rain cap(s), run vertical behind the cab
- They are located at rear corner of cab
  - Split system--one set of components on each corner
  - Single system--located only on one corner

Horizontal Arrangement

- In a horizontal system, exhaust pipe(s), muffler(s), and tail pipe(s) are located under vehicle
- No rain cap is necessary because tail pipe is not pointing up where rain, snow, etc., can come in

Exhaust Operated Components

- Two components of other systems are operated by the exhaust system
  - Turbocharger
    - Utilizes exhaust gases to power turbine portion of turbocharger
    - (Additional information can be found in the air intake portion of this lesson)
  - Exhaust brakes
    - Reroutes exhaust gases, using them to reduce vehicle speed
    - (Exhaust brakes will be covered in depth in the Brake section of this Lesson)

Exhaust System Hazards

- Exhaust gases that escape through trucks exhaust system are composed of
  - Unburned fuel
  - Soot
  - Various toxic fumes
- Can leak into cab and
  - Impair driver performance
  - Cause sickness and possible death
- To prevent leakage of gases, all exhaust components must
  - Be securely mounted
  - Be free of leaks
  - Be operated in accordance with directions in vehicle manufacturers "Operator's Manual"
  - Not be tampered with or altered by a driver
    - Systems are built to comply with strict Federal and State noise and smoke emission laws and regulations
      - State noise and smoke emission laws and regulations

Locating and Recognizing Problems

Air Intake System:

- Look for leaks in system that will allow unfiltered air to get into engine
- Check for clogged or plugged air filters
  - Overly dirty filters may allow dirt to get into the engine
  - Clogged air filters will prevent engine from getting enough oxygen resulting in incomplete combustion, causing
    - Engine to throw out black smoke
    - Injectors to get plugged up
    - Reduced engine power
    - Reduced fuel economy
- Check turbocharger components
  - Oil leakage
    - Not generally caused by turbocharger failures
    - Results from
      - Clogged air cleaner--causes suction that sucks lubricating oil into compressor
      - Kinked or blocked turbocharger oil return line
      - Oil leaks in air brake compressor
  - Turbocharger lubricant--make sure it is
    - Clean
    - Proper weight and grade
- When driving
  - Check mirrors for black smoke
    - Could mean engine is not getting enough air
  - Make sure water does not get sucked into engine
    - Severe damage will result

Exhaust System

- Look for any exhaust system parts that
  - Are not securely fastened
  - Have been damaged or tampered with
- Check for leakage in system
  - Especially leaks allowing gases into cab or sleeper berth
  - Carbon or other residues at system joints will warn driver of possible leakage
- Make sure exhaust is not hitting
  - Tire
  - Fuel system
  - Tarpaulins or cargo
- Use pyrometer to keep exhaust temperature in proper range (if vehicle is so equipped)

Recap

Remember engine must receive an adequate supply of clean dry air to function properly

Always

- Shut down turbocharged engines in conformance with manufacturer's instructions
- Check condition of exhaust system during vehicle inspections
- Operate vehicle
  - In proper gear to avoid high exhaust temperatures
  - So as to avoid unnecessary (and illegal) noise or exhaust emissions

Types of Air Intake Systems

Naturally Aspirated

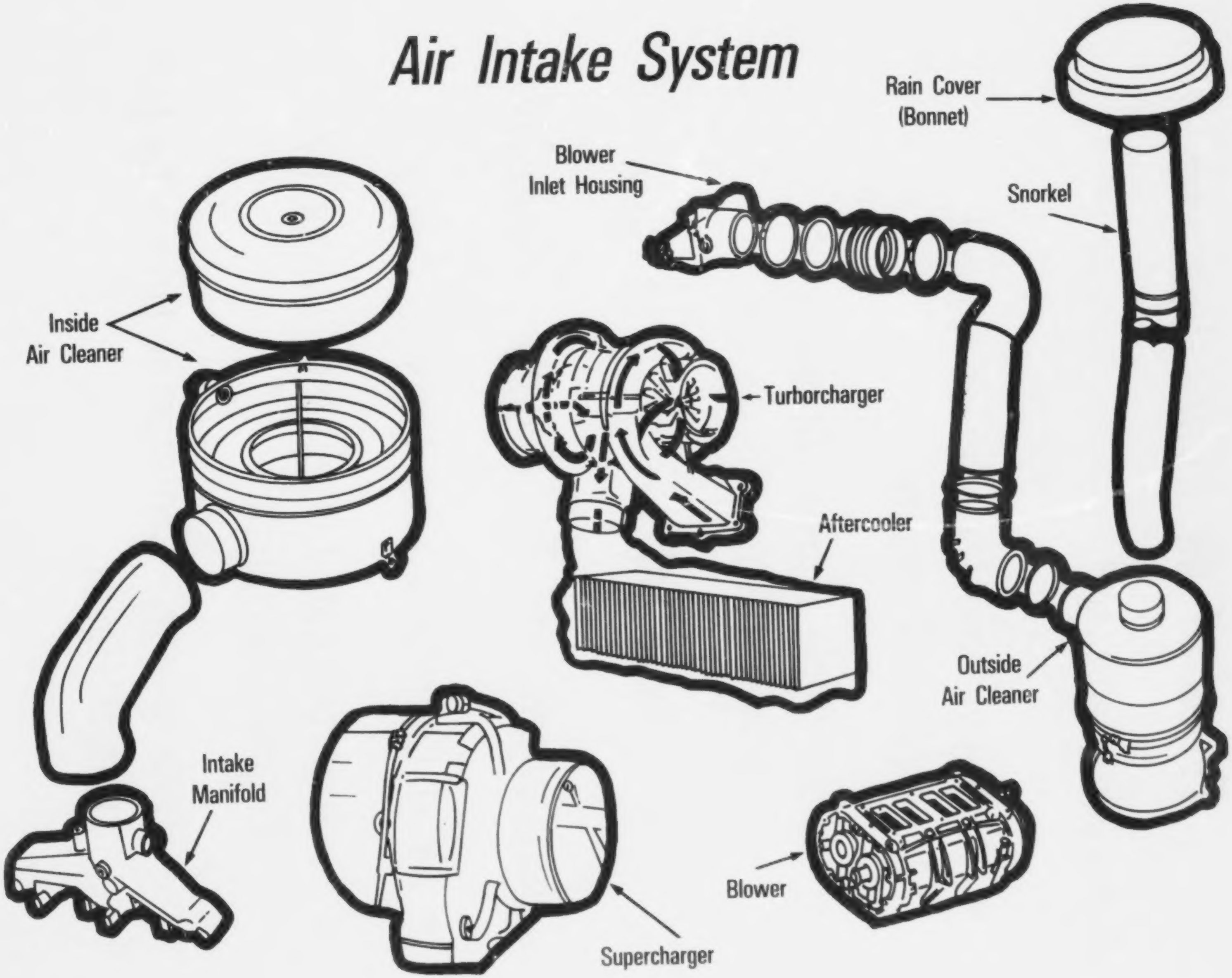
- Air Drawn Into Cylinder at Normal Atmospheric Pressure
  - Four Cycle Engine–Drawn in by Downward Stroke of Piston
  - Two Cycle Engine–Forced in by Blower

Supercharged and Turbocharged Systems

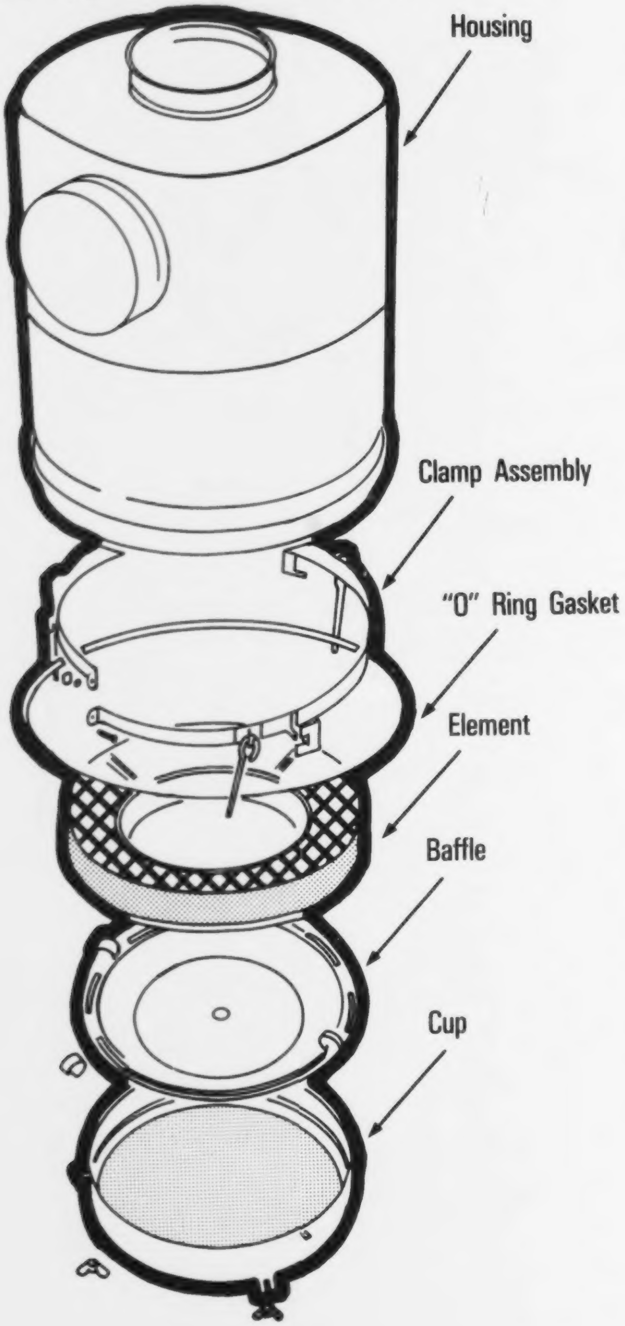
- Air is Compressed for Entering Cylinder
  - Supercharger–Compressor Driven by Engine Crankshaft
  - Turbocharger–Compressor Driven by Hot Exhaust Gases

Visual 4.2

Air Intake System


Rain Cover
(Bonnet)
Blower
Inlet Housing
Snorkel
Inside
Air Cleaner
Turborcharger
Aftercooler
Outside
Air Cleaner
Intake
Manifold
Blower
Supercharger

Wet (Oil Bath) Filter


Housing
Clamp Assembly
"O" Ring Gasket
Element
Baffle
Cup

Visual 4.4

Dry Type Filter

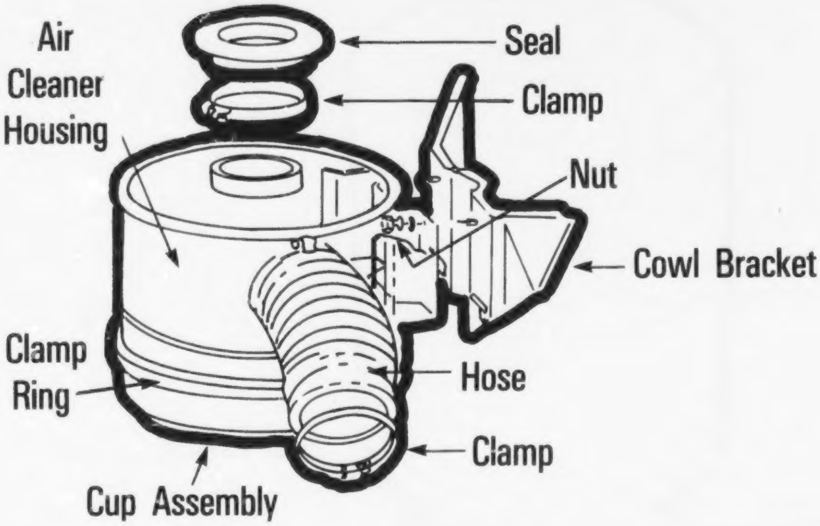

Air Cleaner Housing
Seal
Clamp
Nut
Cowl Bracket
Clamp Ring
Hose
Clamp
Cup Assembly

Figure 4–Diesel Engine Typical Dry Type Air Cleaner (6-71N)

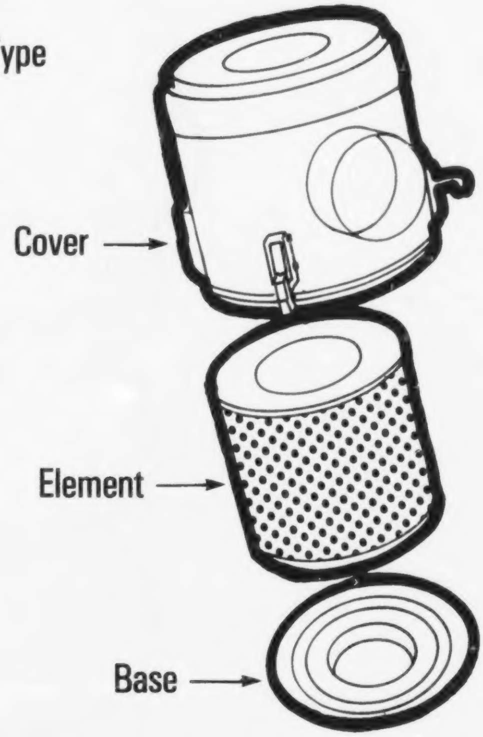
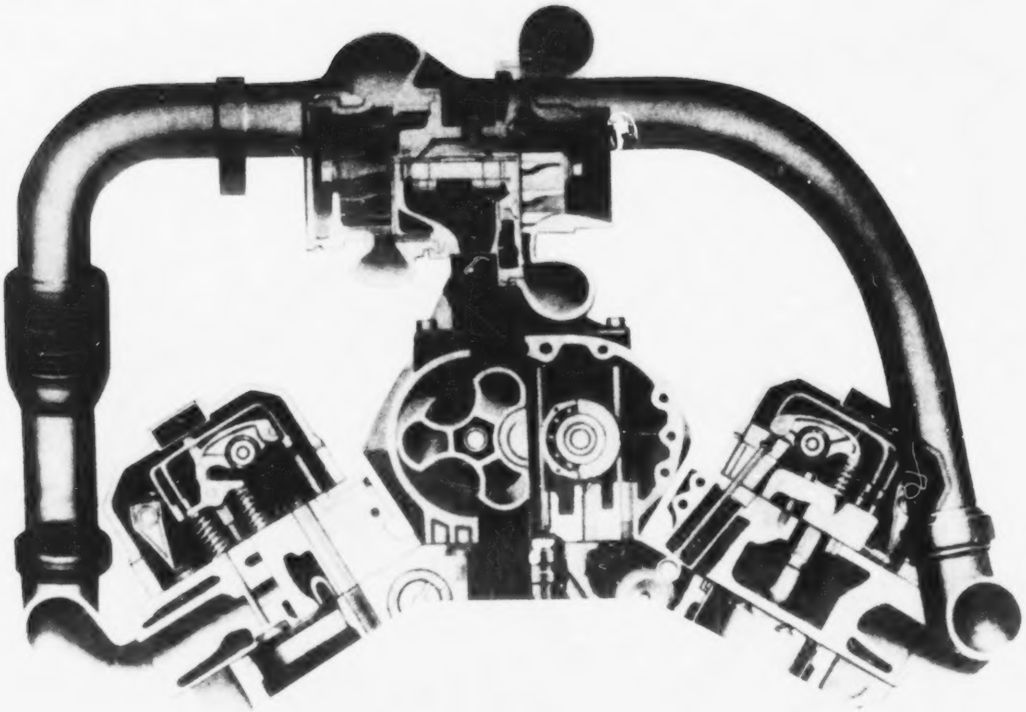

Cover
Element
Base

Figure 5–Diesel Engine Paper Element Dry Type Air Cleaner (16" Caterpillar and Detroit Diesel)

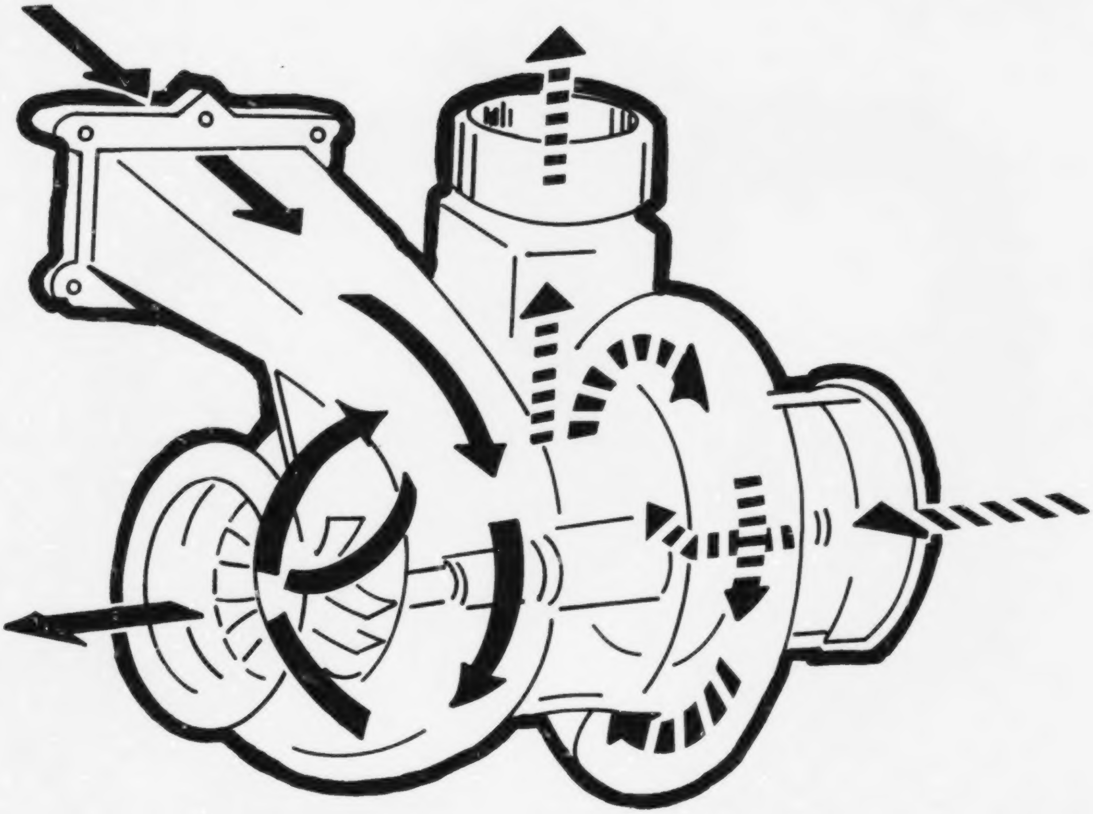
Visual 4.5

Intake Manifold and Valves



Visual 4.6

Example of a Turbocharger

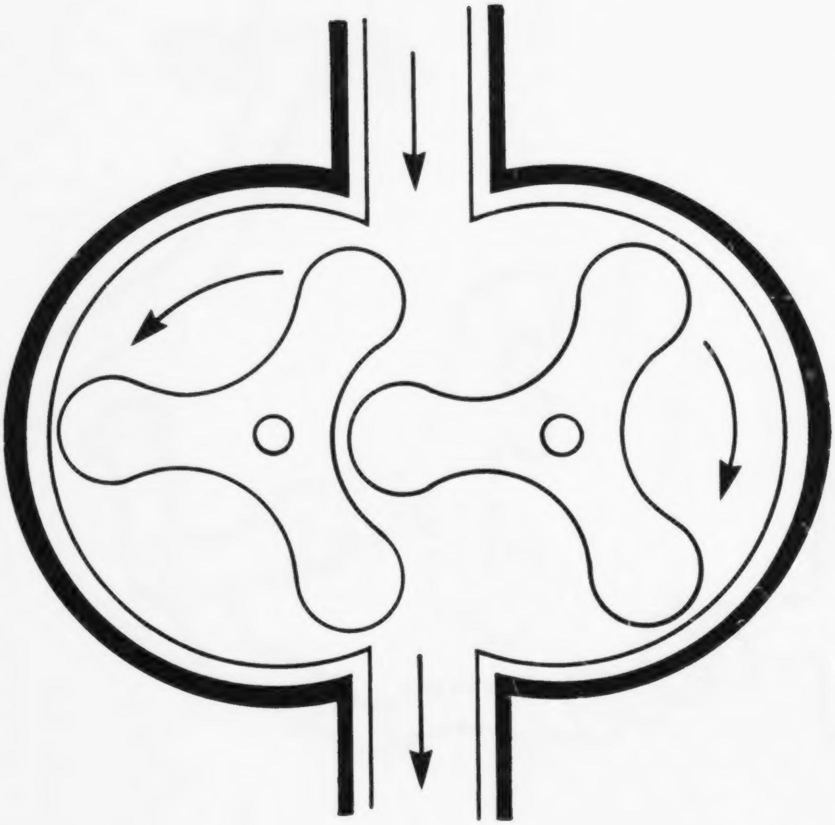


Flow of Exhaust Gases ◀▮▮▮▮▮▮

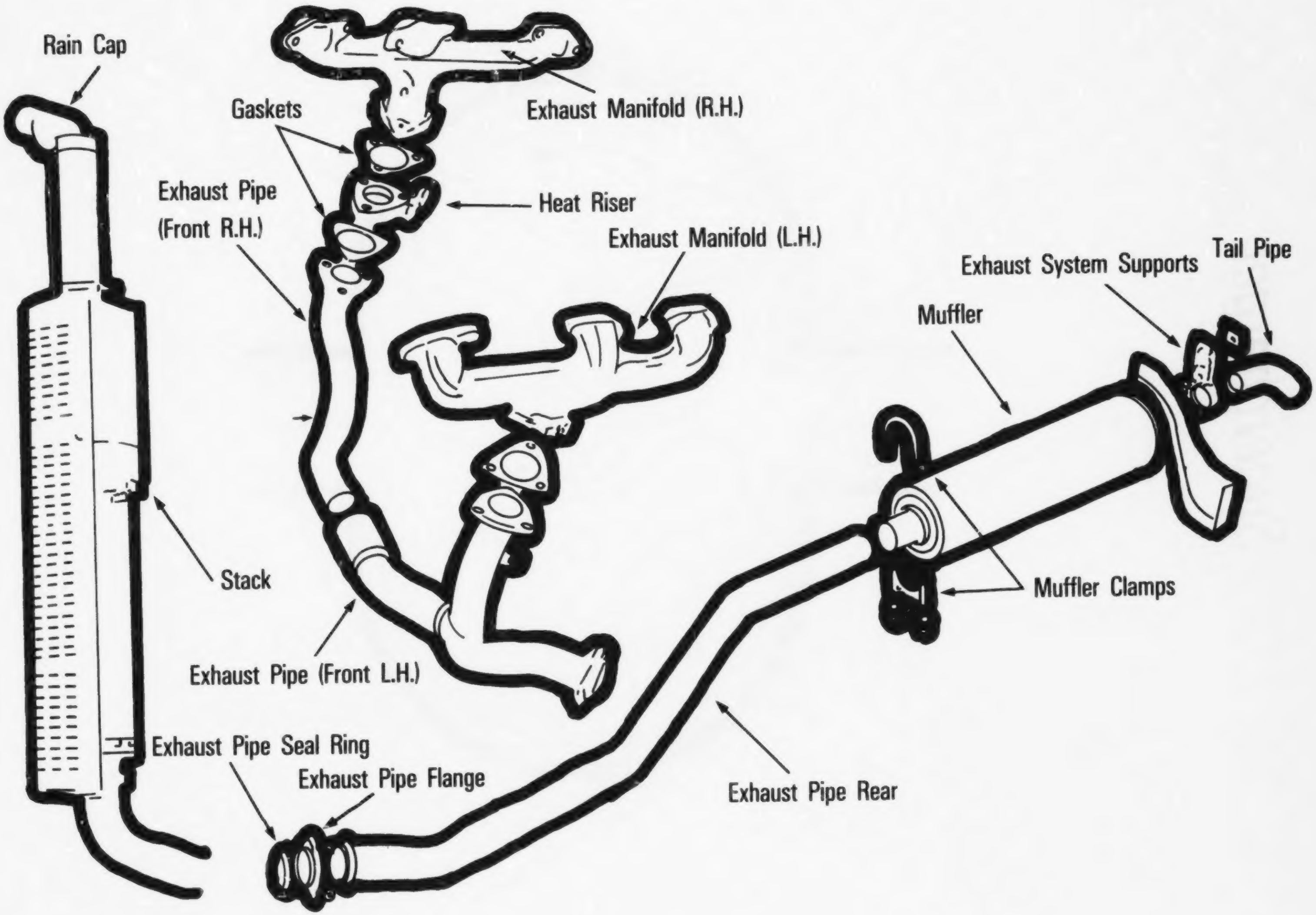
Flow of Intake Air ◀━━

Visual 4.7

Supercharger



Exhaust System


Rain Cap
Gaskets
Exhaust Manifold (R.H.)
Exhaust Pipe (Front R.H.)
Heat Riser
Exhaust Manifold (L.H.)
Exhaust System Supports
Tail Pipe
Muffler
Stack
Muffler Clamps
Exhaust Pipe (Front L.H.)
Exhaust Pipe Seal Ring
Exhaust Pipe Flange
Exhaust Pipe Rear

5. LUBRICATION SYSTEMS (25 minutes)

Introduction

This topic will include a discussion of

- Engine lubrication system components including the oil pan, oil pump, oil galleries and filtration systems
- Types and grades of engine oil
- Functions of engine oil
- Oil analysis programs
- Lubrication systems for other parts of the truck, including the transmission and rear axle, universal joints, wheel bearings, suspension system and steering system

Purpose

The purpose of any lubrication system is

Reduce Friction
- Coats surfaces with a film of oil
- Reduces friction between surfaces
  - Reduces heat
  - Reduces wear

Dissipate Heat
- Heat from friction betwen moving parts is absorbed and carried away by oil
- In engine oil is carried back through oil cooler into oil pan Oil cooler and oil pan both dissipate heat

Keep System Clean
- Carbon, dirt, metal shavings, and other contaminants are picked up by oil
- Contaminants are removed when oil circulates through filter

Seal Parts
- Creates a seal between surfaces in engine
  - Provides a seal between piston rings and cylinder wall
  - Prevents combustion gases from "blowing by" the piston and dissipating power
  - Essential to good engine performance

Absorbs Shock
- Oil between surfaces acts as cushion
- In engine, oil absorbs shock of piston firing

Visual 5.1 Typical Lubricating System

Engine Lubrication

Engine lubrication systems consist of

Oil Pan

Acts as a reservoir

To hold engine oil before it is pumped to the engine
Allows oil to cool
To allow larger contaminant particles to settle out of the oil

Oil Pump

Pulls oil out of the oil pan
Forces oil through the filtration system

Oil Galleries and lines

Allows oil to be pumped through the engine, carrying away heat moving engine parts
Directs oil onto moving engine parts
- Upper engine-rocker arms
- Crankshaft connecting rod bearings
- Supercharger and turbocharger

Oil Cooler

Allow water from cooling system to circulate around oil returning from engine
Water absorbs heat from oil

Internal Distributing Manifold

Passages inside engine block
Distribute oil to lubrication points
Allow drain back into oil pan

Filtration System

Removes impurities from the oil
Oil never wears out, it just gets contaminated

Components and Functions

Basic components of the lubrication system are
- Oil pan
- Oil pump
- Oil filters
- Oil

Visual 5.2 Oil Pan Design

Oil Pan

Located beneath engine block
- Function
  - Collects oil as it is returned from and drips from engine parts
  - Stores oil for recirculation
  - Allows oil to cool
  - Deep enough to prevent spillage as vehicle and engine tilts
- Sump
  - Deep portion of pan
  - Collects dirt and other contaminants
  - Point where oil is usually drained

- Dipstick
    - Extends into oil pan to measure amount of oil
    - Incorrect dipstick can result in
        - Overfilling--waste of oil and damaged engine
        - Underfilling--engine damage
- Suction screen
    - Placed where oil is drawn from pan into oil pump
    - Screens out large particles of dirt and other contaminants
    - Protects oil pump
- Capacity
    - Holds 30-60 quarts of oil
    - Must be kept at prescribed level by frequent checking with dipstick
    - Oil pressure gauge does not measure the amount of oil in lubrication system

Oil Pump

- Draws oil from oil pan and delivers it to lubrication points
- Generator driven by engine crankshaft
- Supplies oil pressure
    - Insufficient pressure results in inadequate lubrication
    - Dashboard oil pressure gauge measures operation of oil pump
- Pumps oil at a rate of 20-35 gallons per minute (at 2,100 rpm)

Filters

- Purpose of filters is to remove dirt and other impurities from the oil
    - Impurities create rather than prevent friction between moving engine parts
    - Greatly accelerate engine wear
    - Filters are one of the most important contributors to long engine life

Visual 5.3 Oil Filtration Systems

Oil Filtration Systems

- There are three different types of filtration systems for a diesel engine
    - Full flow system
        - All oil from the oil pump must pass through a full flow filter
        - Filtered oil goes directly from the filter to engine parts
        - If the filter becomes clogged, a relief valve opens allowing unfiltered oil to reach the engine (unfiltered oil is better than no oil at all)
        - Full flow systems are found in virtually all engines manufactured today
    - Bypass system
        - Only about 10 percent of oil from the oil pump passes through the bypass filter at one time
        - Filtered oil goes back to oil pan
    - Combination bypass full flow system
        - Contains both a full flow and a bypass filter
        - Oil passing through full flow filter goes directly to engine parts

- Oil passing through bypass filter goes back to oil pan
- Bypass filter provides finer "screen" to filter out smaller particles

Visual 5.4 Oil Filters

Types of Filters

Surface Filters

- Filters oil by causing it to pass through a surface
- Removes larger particles from oil
- Large surface area needed to permit oil to flow at a sufficient rate
    - Pleated filters provide large surface area in small place
    - Creates little resistance to the flow of oil
- Surface filters used primarily in full-flow filtration systems

Depth Filters

- Oil passes through bulk material
- Removes small, microscopic particles
- High resistance to oil flow oil flows very slowly
    - Not appropriate to full-flow filters
    - Used primarily in bypass filters

Combined Filters

- Provide both surface and depth filters in a single package
- Surface filter removes large particles
- Depth filter removes small particles
- Surface filter "protects" depth filter, extending the servicable life of the filter

Oil

- Lubricating oil has several important characteristics
    - Viscosity
    - Base number
    - Additives
    - Contaminants

Viscosity

- Viscosity is a measure of the resistance of oil to flow
    - Referred to by "grade" or "weight"
    - A classification system has been developed by the Society of Automotive Engineers (SAE)
        - Each weight or grade is assigned an SAE number
        - The higher the number, the greater the viscosity (the more resistance to flow)
        - Most engine lubricating oil ranges from 10 to 40 weight
- Temperature and viscosity
    - The viscosity of any oil changes with temperature
        - As temperature drops, viscosity increases--oil becomes more resistant to flow
        - As temperataure rises, viscosity decreases--oil flows more easily

- Complicates cold weather operation
    - High viscosity oil (e.g, 30 weight)
        - Engine resists movement of engine parts
        - Engine turns over very slowly
        - Produces hard starting
    - Low viscosity oil (e.g., 10 weight)
        - Allows the engine to start easily
        - Does not lubricate adequately when engine is run

Multi-Viscosity Oil

- Also referred to as multi-weight and multi-grade oil
- Performs like oils of two different viscosity levels
    - Like low viscosity oil when it is cold
    - Like high viscosity oil when it is warm
- Net result is really to maintain same general viscosity regardless of temperature
- EXAMPLE: "10W-30" oil
    - When engine is cold
        - Performs like 10 weight oil
            - Flows easily
            - Allows engine to start quickly
    - When engine is warm
        - Performs like 30 weight oil
        - Provides good lubrication

Synthetic Oils

- Generally are capable of providing a wider range of viscosity than regular oils
- Is claimed to provide better lubrication at normal operating temperatures, resulting in
    - Reduced engine wear
    - Reduced fuel consumption (because of reduced engine friction)
    - Longer period between oil changes
- Contains fewer contaminants than petroleum-based oil
- More expensive than petroleum-based oil
    - Oil price rises reduce the gap between synthetic and natural fuels
    - Difference in cost may be offset by reduced maintenance and operating costs

Additives

- Substances are added to oil to increase their performance
- Viscosity additives
    - Are added to low viscosity oils to improve lubrication
    - Are a component of most multi-viscosity oils
    - Tend to break down over time, requiring frequent oil changes
- Heavy wear additives
    - Help to form a lubrication film on parts
    - Improves the friction reducing qualities of the oil
- Anti-oxidation additives
    - Prevent oxidation of oil
    - Oxidation results in lacquer and varnish deposits on parts

- Anticorrosion additives
  - Neutralize acids
  - Prevent rust

Visual 5.5 Oil Contaminants

Oil Contaminants

Many elements can contaminate oil and lessen its lubrication qualities

- Water
  - Generally formed by
    - Condensation of water vapor in the crankcase during cold weather
    - Leakage from cooling system
  - Water in lubricating system
    - Reduces ability to lubricate
    - Can cause corrosion of internal engine parts

- Sludge
  - Mixture of oil, water, dirt, and other contaminants
  - Results from
    - Water (see above)
    - Oil filters overdue for change
    - Consistently operating at low engine temperatures
      - Short trips
      - Faulty engine thermostats

- Varnish
  - Forms on engine parts
  - Generally results from
    - Oil breaking down under prolonged operation at hot temperatures
    - Poor quality oil

- Other Substances
  - Variety of substances can enter the lubricating system, including

- Fuel
  - Unburned fuel from poorly tuned engine
  - Fuel leakage
  - Reduces viscosity--increases wear
  - Increases volatility (ability to burn) can result in explosion
- Glycol
  - The base material for most permanent antifreeze mixture
  - Combines with oil to form glue-like consistency
  - Can cause engine to seize
- A variety of other substances are formed by additives in oil when oil breaks down from overheating, sustained use, etc.

- Oil Analysis
  - Many fleets send specimens of oil to laboratories for analysis
  - Oil analysis can identify
    - Whether oil needs to be replaced
    - Sources of contamination
    - Engine problems leading to oil contamination

Transmission and Axle Lubrication

Oil is used in vehicle transmissions and axles as well as engines

Purpose

- Lubricates gears and bearings
  - Contact between gears creates sliding friction
  - Contact between bearings produces rolling friction
  - (Concepts of "sliding" and "rolling" friction are described fully in Unit 3.3, Skid Prevention and Recovery)
- Lack of proper lubrication causes
  - Accelerated wear
  - Scoring of parts
  - Possible "welding" of parts

Types of Lubricant

- Transmission and axle oil generally heavier than engine oil
- Needed because of greater pressure on surfaces
- 140 weight oil is common
- Is designed to withstand greater pressure

Contaminants

- Dirt is the primary contaminant
- Results from dirt around filler plugs and openings when lubricant is added
- Causes wear of gears and bearings

Other Lubrication Points

A variety of other vehicle components require periodic lubrication

Components

- Wheel bearings
  - Type of lubricant
    - Grease
    - Oil bath
  - Lack of lubricant can cause bearings to burn out
    - Can cause damage to axle
    - Can result in loss of wheel and a possible accident
- Fifth wheel
  - Lubrication needed for smooth articulation
  - Lack of lubricant can cause binding in cold weather
  - Can interfere with steering, cause possible jackknife
- Suspension
  - Spring hangers, and parts of steering system may require lubrication
  - Grease fittings provided where lubrication is required
  - Newer vehicles tend to have sealed components
- Steering components
  - Steering components will be described and discussed under "Steering Systems"

Type of lubricant
- Different lubricants required for various components
- Important to use exactly the right lubricant
- Improper lubricants can cause
  - Improper operation
  - Damage to components

Locating and Recognizing Problems

Inspection

During vehicle inspections it is vital that drivers check for any signs of

- Visible leakage in the lube oil system for the engine
- Evidence of
  - Crimped oil lines
  - Plugged, leaking or damaged primary and secondary oil filters
- Water (coolant) or other forms of contamination of oil when pulling dipstick to check oil level
- Leakage of lubrication from wheel
- Bearings, transmissions and drive axles

Servicing

Drivers must be sure that
- The engine crankcase is kept filled to the proper level (without overfilling)
- They use the proper grade and type of oil as specified by the vehicle operators manual and/or supervisor.
- The fifth wheel is properly lubricated, particularly in cold weather

Care must be taken when wiping the engine dipstick and/or adding oil
- To allow no foreign material/dirt to enter the system
- Costly damage or engine failure can quickly result

Operation

During operation, drivers must
- Operate engine at rpm's necessary to maintain proper readings
- Monitor engine oil, transmission, differential and/or axle temperature gauges (if provided)
- Keep track of oil consumption and be alert for any significant changes
- Consult operators manual and/or supervisor for instructions
- If strange noises start to come from the engine:
  - Check lube oil temperature and/or pressure immediately
  - Shut engine down immediately if temperature/pressure is no longer in the "safe" or "normal" operating ranges
  - Failure to shut down engine promptly and seek out source of the problem can result in serious engine damage and/or failure
  - Modern, high power diesel must have lots of clean lubricating oil in order to function
  - Absence of this lubrication can almost immediately cause severe damage due to excess heat and/or friction

Post-Trip

Drivers must report promptly any condition indicating lack of proper lubrication noted during operation

Recap

Lube oil is the "blood" of the diesel engine--without it the engine may fail within seconds

Dirty or contaminated lube oil will also quickly damage an engine

Various types of oils have been specially formulated for various types of service--they must never be mixed

Drivers are responsible to see to it that

- Their vehicle's engines are always sufficiently supplied with the proper type of oil
- Whenever oil is added to the engine, care is taken to prevent dirt from entering system

Drivers must be on the alert for

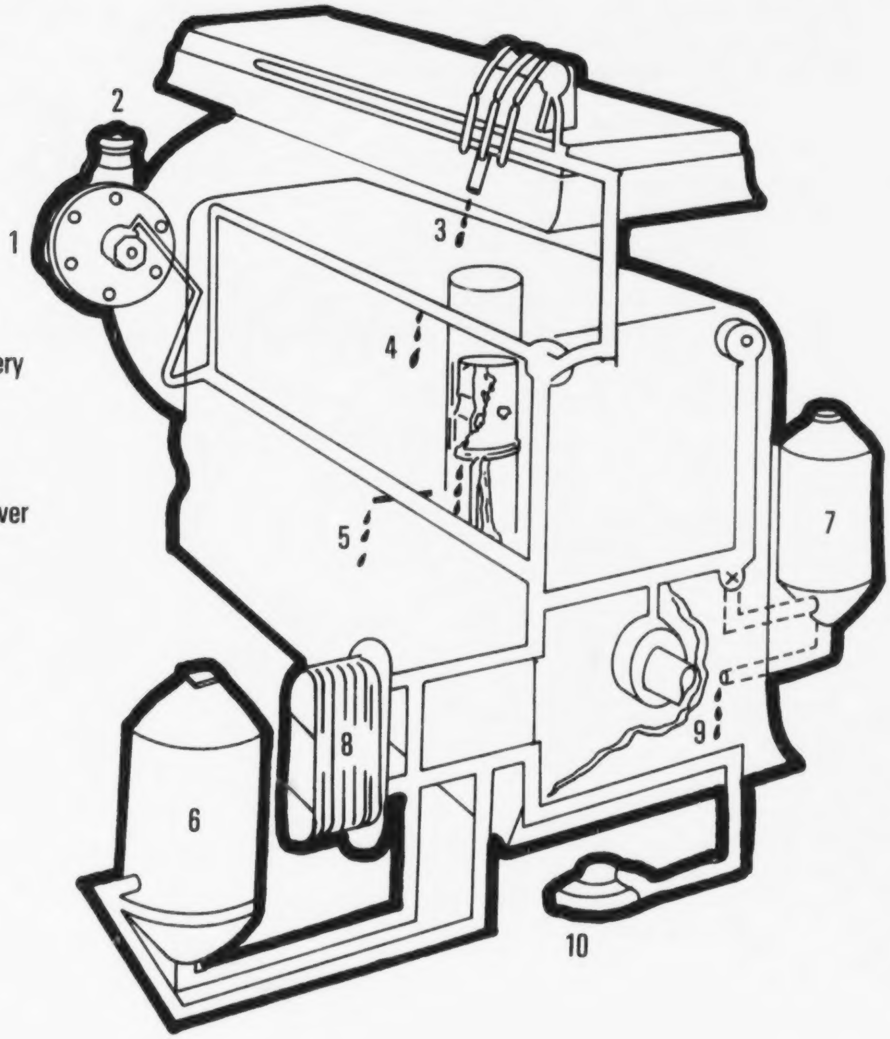
- Any sign of system malfunction
- Changes in oil consumption rate
- A change in the appearance of the oil

Drivers must report any such changes to supervisor promptly

Visual 5.1

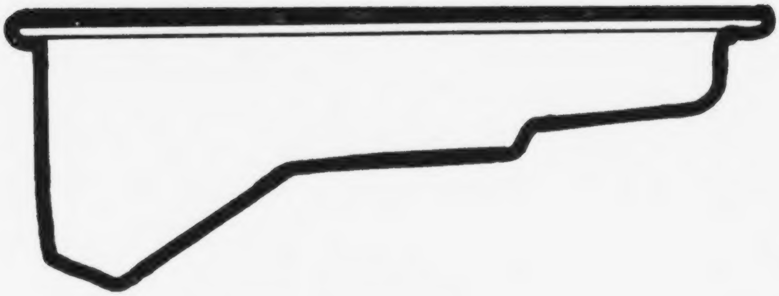
Typical Lubricating System

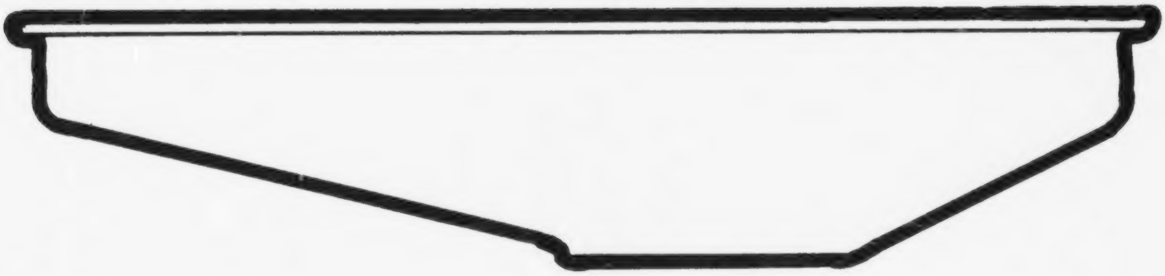
1. Oil From Main Gallery
2. Oil Filler
3. Rocker and Drain
4. Cam Pocket Drain
5. Oil Drain From Blower
6. Full Flow Filter
7. Bypass Filter
8. Oil Cooler
9. Drain to Oil Pan
10. Inlet Screen



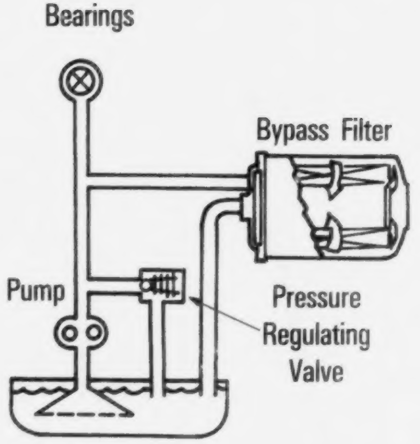
Visual 5.2

Oil Pan Design

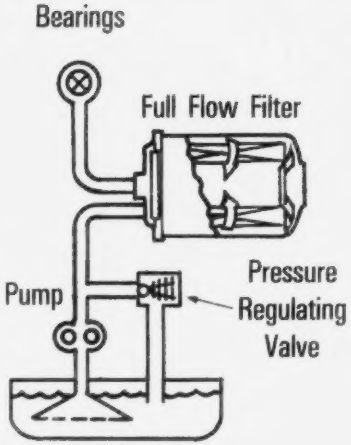




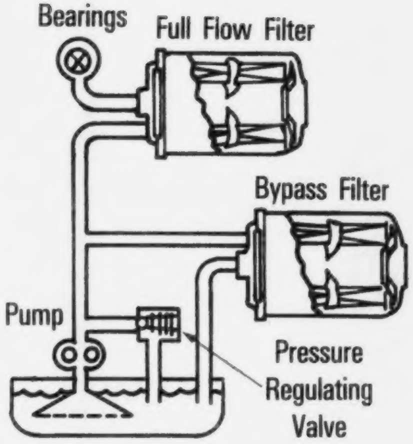
Oil Filtration Systems


Bearings
Bypass Filter
Pump
Pressure
Regulating
Valve

Full Flow Lube Oil System


Bearings
Full Flow Filter
Pump
Pressure
Regulating
Valve

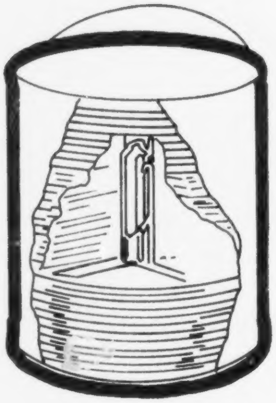
Bypass Lube Oil System


Bearings
Full Flow Filter
Bypass Filter
Pump
Pressure
Regulating
Valve

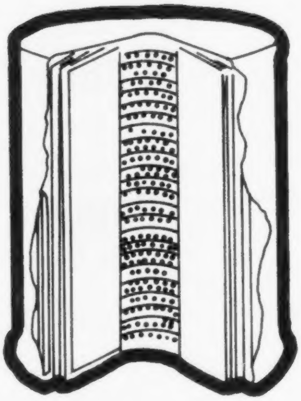
Combination Lube Oil System

Visual 5.4

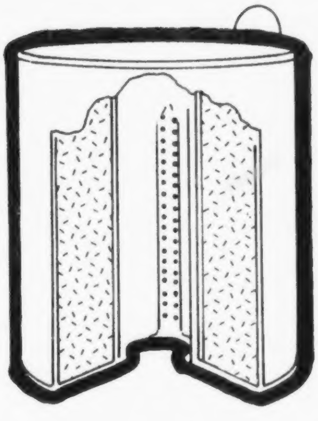
Oil Filters



Depth Type



Surface Type



Combination Type

Visual 5.5

Oil Contaminants

Water

Sludge

Dirt

Fuel

Glycol

6. COOLING SYSTEMS (30 minutes)

Introduction

This section is intended to provide students a fundamental knowledge of

- Methods used for controlling the internal temperature of diesel engines
- Operating principles of major components of the cooling system
- Types and composition of coolants
- The role of the cooling system in maintaining sufficient engine temperatures to
  - Support complete combustion
  - Simultaneously carry away excess heat that could cause engine failure
- The importance of a properly maintained and operating cooling system to safety and economy of vehicle operation

Purpose

The purpose of the cooling system is

- To regulate the amount of heat retained in the engine
- Heat generated by burning fuel

Diesel Engine Cooling

- Heat from compressed air causes combustion
- Engine temperature must be controlled for maximum efficiency
  - Not hot enough--incomplete combustion occurs
  - Too hot--causes engine damage
- Handles about one-third of the engine heat
  - One-third is converted into power to drive the vehicle
  - One-third goes up the exhaust pipe unused
  - One-third must be removed by the cooling system
- Cooling system also used to cool
  - Turbocharger
  - Engine oil
  - Transmission lubricant
- Cooling system provides heat source for
  - Cab heater
  - Window defrosters

Basic Cooling Systems

Visual 6.1 Typical Cooling System

Using the visual, trace the flow of water through the cooling system as follows

1. Cold water flows from the bottom of the radiator.
2. Passes through oil cooler to cool engine lubricating oil.
3. Passes water pump, which creates a flow of water through the cooling system

3. Passes water pump, which creates a flow of water through the cooling system.

4. Passes through the engine water jacket, where it absorbs heat from the engine.

5. Is collected in the water manifold for return to radiator.

6. A portion of the water flows through the filter where impurities are removed.

7. Before water reaches maximum temperature, it flows through the bypass tube where it is recycled through the engine by the water pump.

8. When the water reaches maximum temperature, the thermostat opens and allows water to flow to the radiator.

9. Water flows downward through the radiator, where it is cooled, and returns to the engine.

Components and Functions

Visual 6.2 Centrifugal Water Pump

Centrifugal Water Pump

- Literally the heart of the cooling system
  - Pumps water through cooling system
  - Must circulate water fast enough to dissipate heat
  - Typical tractor engine water pump pumps several thousand gallons per hour
- Most water pumps are of the centrifugal type
  - Rotating fan or "impeller" blade scoops up water and spins it by centrifugal force through the pump
  - Very few use a plunger or diaphragm as in a fuel pump
- Driven by a belt attached to the crank shaft pulley or gear driven

Visual 6.3 Radiator

Radiator

Large "tank" in the front of the engine compartment through which hot water from the engine flows

Function: Radiates (dissipates) heat absorbed by engine

Operation
- Water enters receiving tank at top of radiator
- Flows down through small passages in radiator
- Passages are very narrow (e.g., tubes)
- Air flows over passages
- Creates a large surface area for cooling
- Cools water very quickly
- Heat dissipates into the air around the radiator

- Water collects in dispensing tank at bottom of radiator
- Water passes from dispensing tank to engine and water pump through a hose

Receiving Tank

- Cools water prior to circulation through core
- Keeps top of water passages from being exposed to air
- Vertical baffles often divide the receiving tank into sections
    - Reduce the turbulence of the water in the receiving tank
    - Turbulence can lead to air bubbles in the coolant supply
    - Air reduces cooling system efficiency and can lead to corrosion

Filler Pipe

- Located at top of radiator
- Allows coolant to be added to radiator

Pressure Cap

- Closes top of filler pipe
- Maintains moderate amount of pressure in cooling system
    - Pressure created by heat expansion
    - Improves circulation of water
- Relief valve releases excess pressure
    - Excess pressure caused by excessive heating of coolant, e.g., boiling over
    - Prevents radiator from bursting
    - Also lets in air if necessary as radiator cools
    - Keeps radiator core from collapsing from low inside air pressure

Radiator Core

- The place where heat is dissipated
- Consists of many small passages connecting receiving tank to dispensing tank
    - Most radiators use thin copper tubes
    - Air passes over tubes
    - Cools water passing through tubes
- Thin, horizontal fins or "vanes" channel the air through core
- Size of core
    - The larger the core:
        - The more tubes there are
        - The more water can flow through the core
        - The more heat can be dissipated
    - Core size must be designed to meet the cooling needs of the engine

Visual 6.4 Radiator Fan and Fan Shroud

Radiator Fan

Function

- Draws air through radiator
- Necessary when vehicle is not moving fast enough to ram air through radiator core

Construction

- Similar to ordinary home cooling fan
- Slanted blades connected to shaft

- As blades revolve, they push the air
- Driven by belt connected to crankshaft

Fan Shroud

- Surrounds the fan
- Increases suction of the fan
  - Allows only air from radiator to be drawn through fan
  - Particularly important when fan is too small to cover the entire core area

Temperature-Controlled Fans

- Controlled by thermostat (to be discussed in a moment)
- Clutch-operated
  - Drive belt connected to fan through a clutch
  - Thermostat turns on fan
    - Turns on fan only when engine runs too hot
    - Does not operate when:
      - Engine is warming up
      - Speed of vehicle is sufficient to ram air through engine
- Variable-speed
  - Speed of fan varies with temperature. The hotter the engine the faster the fan turns and the more cooling occurs
  - Drive pulley connected to fan through a fluid coupling
  - As engine temperature increases, more fluid is forced into the coupling
  - As more fluid enters the coupling, the fan runs faster
- Benefits
  - Reduces fan wear by reducing operating time
  - Improves fuel economy
    - Fan consumes 1-5 percent of engine power
    - Turning fan off reduces fuel consumption

Visual 6.5 Thermostat

Thermostat

- Consists of a valve at the top of the engine block
- Opens and closes as water temperature changes

Function

- Regulates flow of coolant through the cooling system
- Controls water temperature
- Maintains the engine at proper operating temperature
- Regulates flow of coolant between engine and radiator receiving tank

Operation

- Cold Engine
  - Thermostat closed
  - Blocks flow of coolant to radiator
  - Coolant is forced through bypass hose to water pump
  - Water recycled through engine without cooling
  - Temperature of the water gradually increases

- Engine Warming
  - Thermostat opens partially
  - Coolant able to flow through radiator
  - Heat is dissipated
  - Temperature of the water and engine is maintained
- Engine Overheats
  - Temperature of the coolant increases
  - Thermostat opens completely
  - More coolant passes through radiator
  - More heat is dissipated
  - Temperature of coolant drops
  - Engine temperature returns to normal
- Opening and Closing the Thermostat
  - Maintains proper operating temperature
  - Can vary up to 20°
    - Slow response of thermostat causes a delay in temperature change
    - Control of coolant flow not precise

Visual 6.6 Water Filters

Water Filters

Consists of a small cannister through which water flows.

Function

- To remove impurities from coolant
- Types of impurities
  - Particles--dirt, sand, silt, metal, rust and other corrosives
  - Debris--pieces of hose, thermostat gasket
  - Substances--oil, precipitated additives, minerals from water or antifreeze

Operation

- Work as a "bypass"
- Only a portion of coolant passes through filter at any one time
- Placing filter in main flow of coolant would
  - Rate of flow
  - Reduce cooling capacity
  - Cause overheating

Benefits

- Prevents blockage of coolant flow
  - Particles in debris can clog radiator tubes
  - Result in overheating
- Protects interior of cooling system
  - Impurities can cause corrosion of radiator, hoses, engine
- Reduces wear
  - Particles and chemicals can cause fuel pump wear
  - Cause fuel pump to give out prematurely

Coolant

The term refers to whatever substance is used in the cooling system

- Function
  - Carries the heat from engine to radiator
  - Forms the "medium" through which heat is dissipated
- Composition
  - Coolant is a mixture of
    - Water
    - Antifreeze
    - Conditioners
  - Water
    - Principal component of most coolant mixtures
    - Is the component primarily responsible for absorbing and dissipating heat
    - Water varies in quality
      - Mineral content--generally referred to as "hardness of water"
      - Sulfates and other minerals
      - Various chemicals that enter the water supply come from mining, industrial plants
      - Impurities can cause damage
    - Minerals can cause radiator tubes and other metal components to rust
    - Chemicals can cause corrosion of metal, hoses, seals
    - As water evaporates, deposits can form, blocking flow of coolant
- Antifreeze
  - Purpose
    - Keeps water from freezing
    - Prevents damage due to expansion as ice is formed
      - To engine: can cause block to crack
      - To cooling system components: can burst radiator hoses, water pump seal
  - Types
    - Ethylene-Glycol--Most commonly used
    - Ethylnol (Ethyl-Alcohol)--Tends to evaporate
    - Methanol (Methyl-Alcohol)--Flammable
  - Amount
    - Depends on amount of water in cooling system
    - Check operator's manual
    - Can also be measured by mechanic using hydrometer
- Conditioners
  - Function
    - Neutralizes minerals and chemicals in water
    - Prevents corrosion and formation of deposits

- Types
  - Rust inhibitor--coats surface of metal parts to prevent rust
  - Water softeners--causes chemical reaction in "hard" water to prevent formation of deposits
  - Water pump lubricant--lubricates revolving parts of water pump
- Often added to antifreeze
  - Does not remain as effective as long as antifreeze does
  - Must be periodically replenished

Visual 6.7 Radiator Shutters

Radiator Shutters

A set of shutters or louvres placed in front of radiator

Function

- Controls flow of air through the radiator
- Helps keep engine operating at proper temperature

Operation

- Opens and closes like a venetian blind
- Setting of shutters determines the amount of air that can pass through the radiator
- Shutter settings controlled by thermostat
  - When engine is cold
    - Shutters are closed
    - Prevents air from passing through radiator
    - Allows temperature to rise
  - When engine reaches proper temperature
    - Shutters open enough to allow some air to pass through
    - Shutters open and close slightly to keep engine at proper temperature
  - When temperature too high
    - Shutters open wide to let more air pass through
- Shutters improve on performance of thermostat
  - Shutters keep engine within 6° of optimum temperature
    - Give "fine-tuning": slight change in the shutter position produces slight change in air flow
    - Regulate temperature more precisely than thermostat
  - Thermostats can vary as much as 20°
    - Thermostat gives "coarse" control: slight change in setting produces big change in water flow
- Shutters should not be used with temperature-controlled fan
  - Operation of fan with shutters closed
    - Produces drag on fan drive
      - Increases wear
      - Wastes fuel
    - With variable speed fan
      - Closed shutters increase temperature
      - Cause fan to work even harder

Visual 6.8 Winter Front

Winter Front

Covering fastened over the tractor grille during cold weather

Function

- Limits the flow of air through the radiator
- Causes engine to run at hotter temperature
- Can improve engine performance where thermostat does not effectively control temperature

Construction

- Made to be easily fastened and removed
- Should not cover the grill completely
  - Restricted air supply causes drag on fan
  - Results in excessive wear

Winter fronts should not be used with variable-speed fans
- Rising engine temperature causes fan to work harder
- Fan and winter front are working against each other

"Homemade" winter fronts
- Many drivers place cardboard on front of grille for radiator
- Typically done to raise heater output and increase temperature in cab--very dangerous practice that can cause severe damage
- Restricts flow of air
- Places drag on fan
  - Increases wear
  - Increases load on engine to reduce mpg
- Better to plug air leaks in doors and windows

Hoses

Carry coolant between radiator and engine
Different hoses designed for different purposes

Size (diameter)

- Designed to furnish different capacities
- Engine or radiator fitting designed for particular size
- Improper size can result inadequate cooling, leakage around the fitting

Construction

- Hoses made of different types of material, different thicknesses to provide necessary flexibility and strength
- Some hoses reinforced with internal coiled wire to prevent collapsing

Visual 6.9 Damaged Hoses

Hose Problems

Hoses subject to a variety of damage

- Corrosion--from water impurities, chemicals, oil (e.g., from leaking oil cooler)
- Hardness, Cracking--from excessive heat, cold, vibration, ozone, or just age
- Swelling--from excessively hot cooling
- Scuffing, Abrasion--from rubbing against engine parts, exposure to dirt, stones
- Breaking--from improper tightening, flying debris

Belts

A series of belts are connected to crankshaft pulley to drive

- Cooling System--Water pump and fan
- Accessories--Alternator, air compressor, power steering pump, and other accessories

Requirements for effective opertion of belts include

- Fit--Each belt must be designed to fit the drive pulleys and driven pulleys
- Length--Must be correct length or belt cannot be properly tensioned
- Width, Depth and Shape--Must fit pulley exactly or wear and slippage can result
- Tension--Proper tension is required for effective operation and long belt life
  - Inadequate Tension results in
    - Equipment driven by belts does not operate properly
    - Friction from slippage generates heat which causes damage to bearings and other parts
    - Inside of belt can become polished and hard, necessitating replacement
  - Overtensioning results in
    - Strain on shafts and bearings
    - Failure of fan, water, pump or accessories
    - Excessive belt wear
- A gauge should be used to get proper tension

Matching

- On multiple-belt drives, the belts must be of identical size, width, and shape
- If belts are not exactly the same size, they cannot be properly tensioned
- Mismatch often occurs when one belt wears out
  - New belt is usually shorter than old belt
  - All belts have to be replaced at the same time

Pulleys--Must be in proper operating condition for effective operation and long belt life

Worn Pulleys

- Can cause belt to ride too low in the pulley groove
- Can result in slippage and excessive wear
- Should be checked occasionally with a straight edge
  - Lay straight edge across the two pulleys
  - Should not be gaps between straight edge and pulley

Misaligned

- Can cause fraying of belt sidewalls
- Can prevent proper tension
- Should be checked occasionally with a straightedge
  - Lay straight edge across the two pulleys
  - Should not be gaps between straightedge and pulley

Water Jacket

- The "water jacket" is a space within the engine block surrounding the cylinders
  - Water flows through the space, creating a "jacket" around cylinders
  - Absorbs heat from cylinders
  - From air compression
  - From combustion
- Walls of water jacket susceptible to corrosion and formation of deposits, as described in earlier discussion of "Coolant"
  - Can interfere with heat transfer and produce "hot spots" in engine wall
  - Deposits and "scaling" of engine walls can clog cooling system
  - Problem reduced by use of water conditioners

Locating and Recognizing Problems

Inspection

- During vehicle inspections, drivers must check for any signs of
  - Visible leakage of coolant from any source
  - Belts that are too tight or too loose, belts must have slight amount of slack when pushed down with the fingers
    - It is best to use a tension gauge
  - Noisy, cracked, or frayed belts
  - Belts imbedded with frayed material or oil soaked
  - Cracked, bulging, or otherwise damaged radiator hoses
  - Fans which are damaged or malfunctioning

- Radiator shutters malfunctioning
  - Radiator pins plugged with bugs, leaves or other types of foreign debris restricting air flow
  - During cold weather, homemade winter fronts improperly placed by other drivers

Servicing

- Drivers must be sure that
  - The engine cooling system is kept filled to its proper level
  - That mixture of coolant is properly maintained by not adding plain tap water to replenish coolant level if it is low

Operation

- While operating the vehicle, drivers must take care to
  - Keep engine at proper rpm to maintain required operating temperature range
- Monitor instrument panel gauges for temperatures running too hot or too cold
- At first signs of change in temperature, immediately stop and locate cause

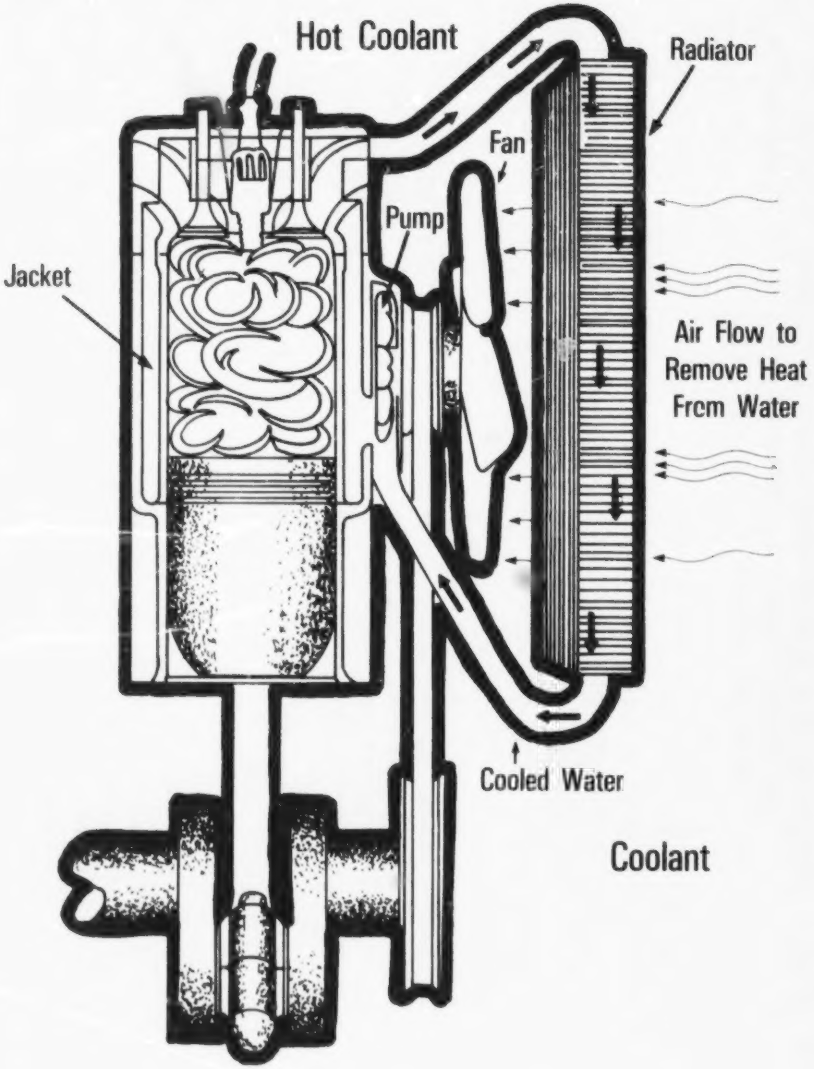
Post-Trip

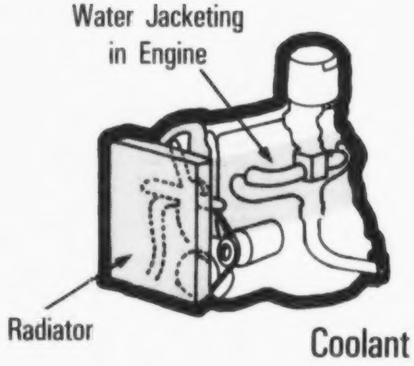
- Drivers must promptly report any condition including
  - Loss of coolant
  - Difficulty in maintaining proper coolant pressure in air temperature
  - Plain tap water with its adverse chemicals should never be added to the cooling system of a diesel engine
  - Any approved coolant mixes specified by supervisor should be added
- Drivers must be responsible to see that their vehicle's cooling system is adequately supplied with clean coolant

Recap

- Drivers must be constantly on the alert for
  - Any sign of cooling system malfunction
  - Any change in the consumption or evaporation of coolant or any change in the appearance, temperature, or pressure of the coolant
  - Finally, drivers must report any such change to their supervisor promptly
- Driver must ascertain either from operator's manual or supervisor
  - The safe operating range that has been determined for the coolant and that particular vehicle
  - Temperature range constant and, if unable to determine, report it immediately for correction

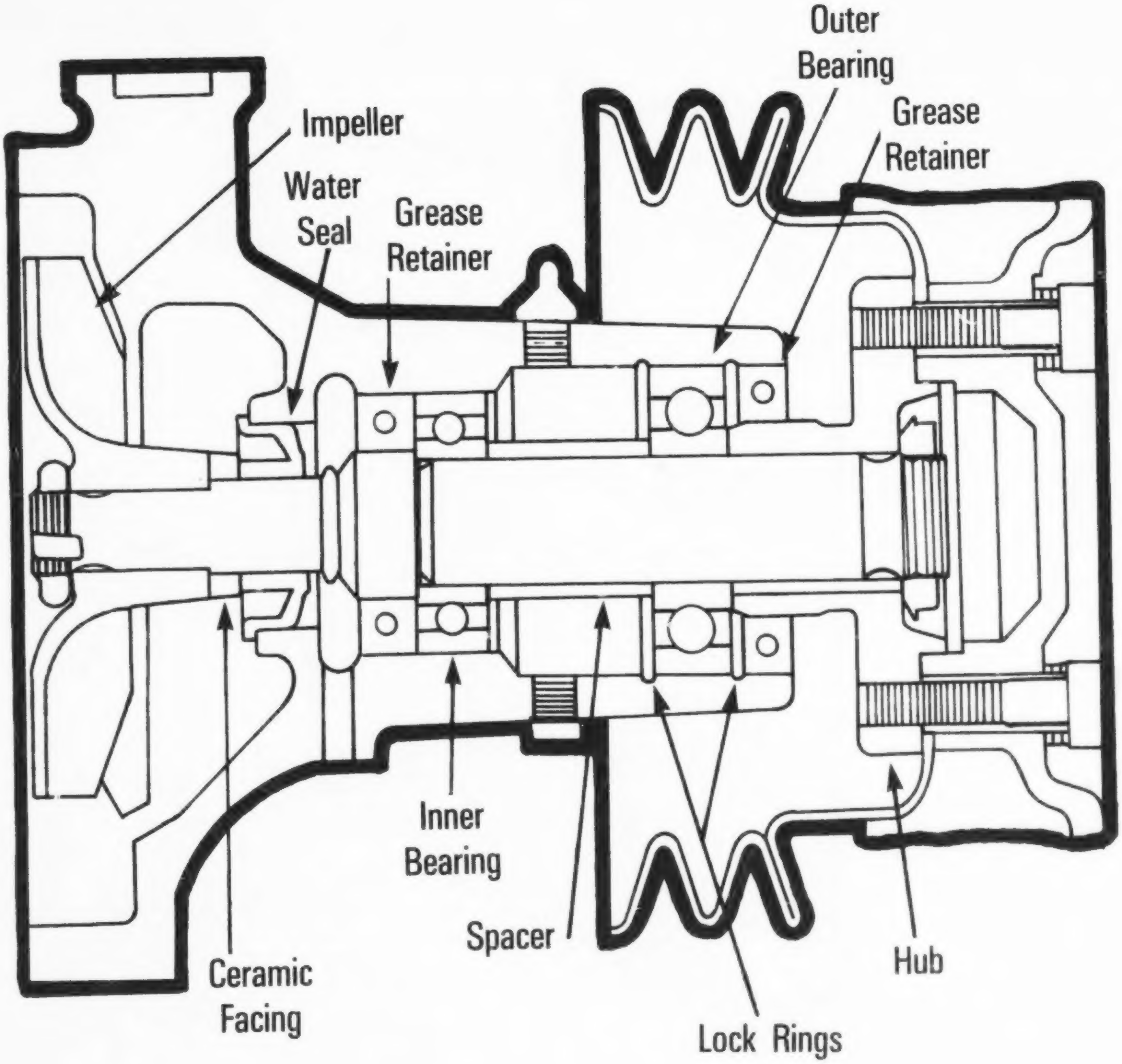
Cooling System


Hot Coolant
Radiator
Fan
Pump
Water Jacket
Air Flow to
Remove Heat
Frcm Water
Cooled Water
Coolant


Water Jacketing
in Engine
Radiator
Coolant

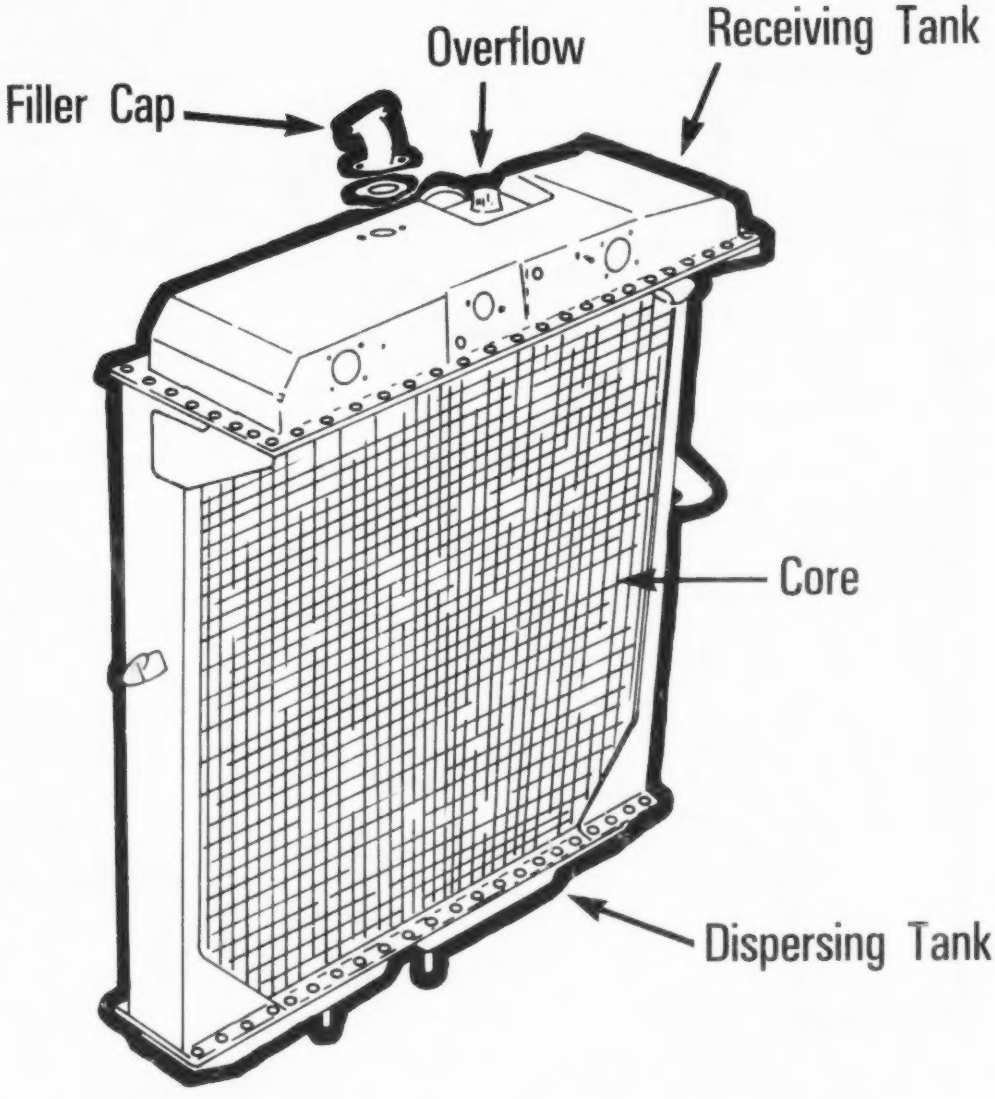
Visual 6.2

Centrifugal Water Pump


Outer Bearing
Impeller
Grease Retainer
Water Seal
Grease Retainer
Inner Bearing
Spacer
Ceramic Facing
Hub
Lock Rings

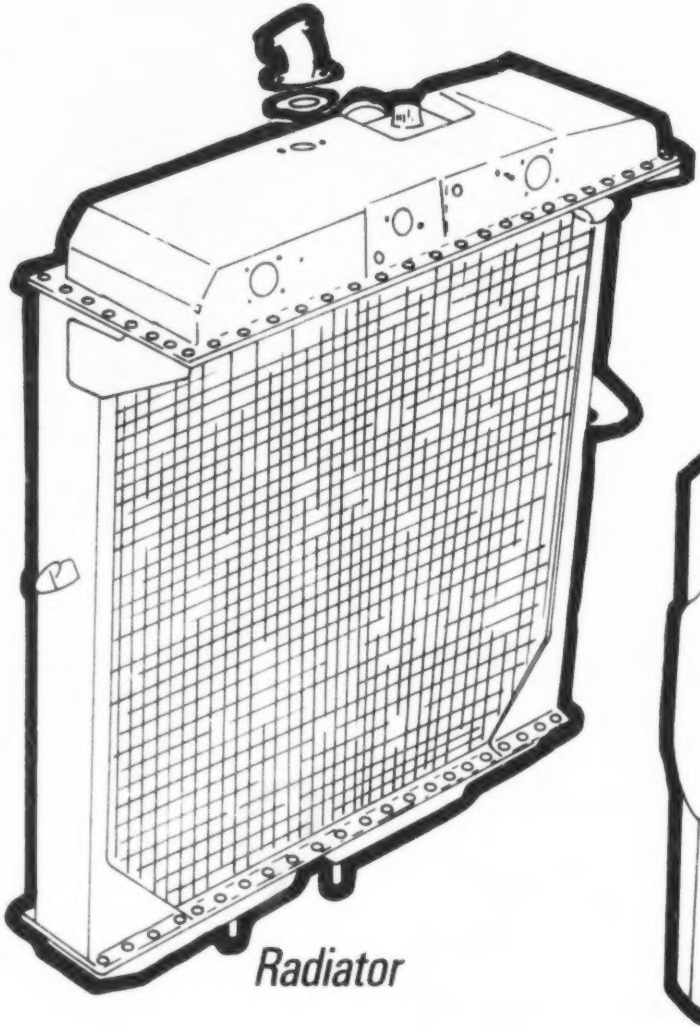
Visual 6.3

Radiator

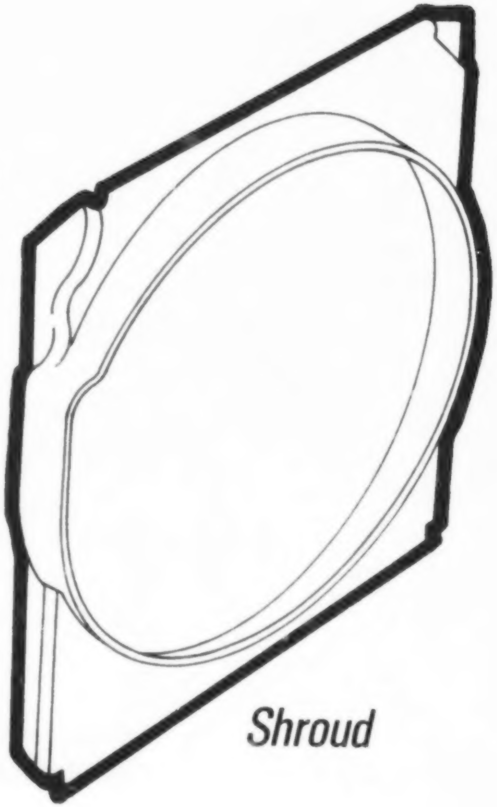

Filler Cap
Overflow
Receiving Tank
Core
Dispersing Tank

Visual 6.4

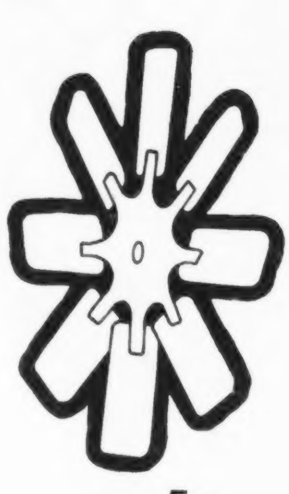
Radiator Fan and Shroud



Radiator



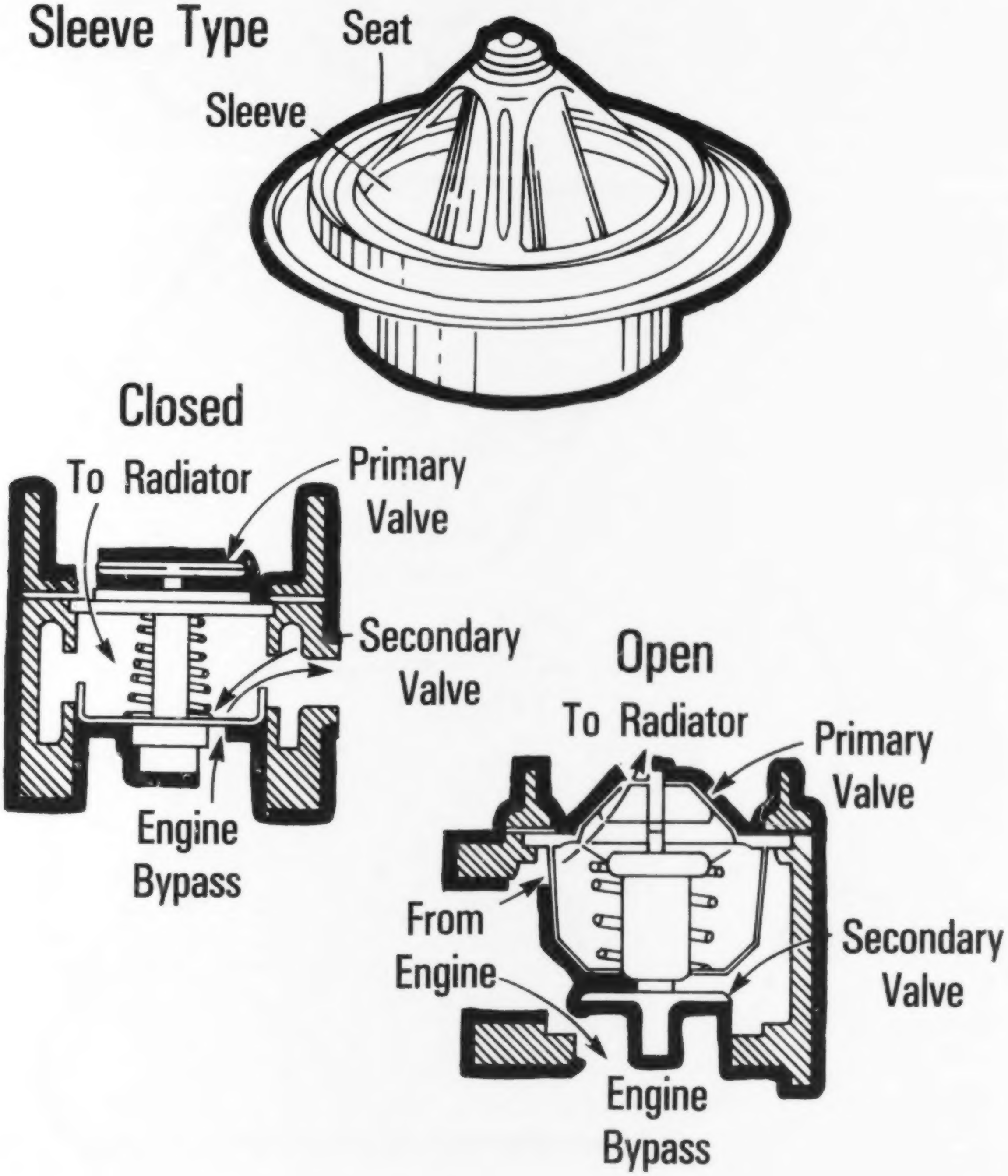
Shroud



Fan

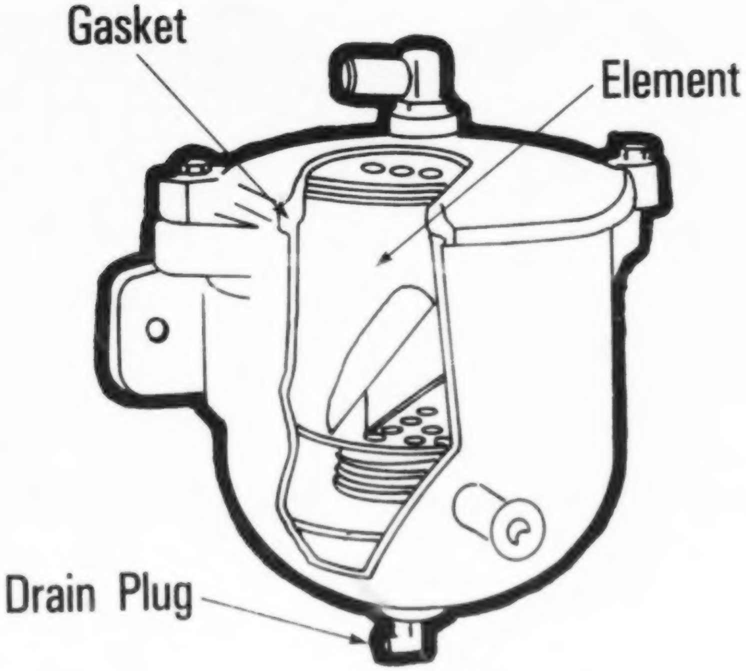
Visual 6.5

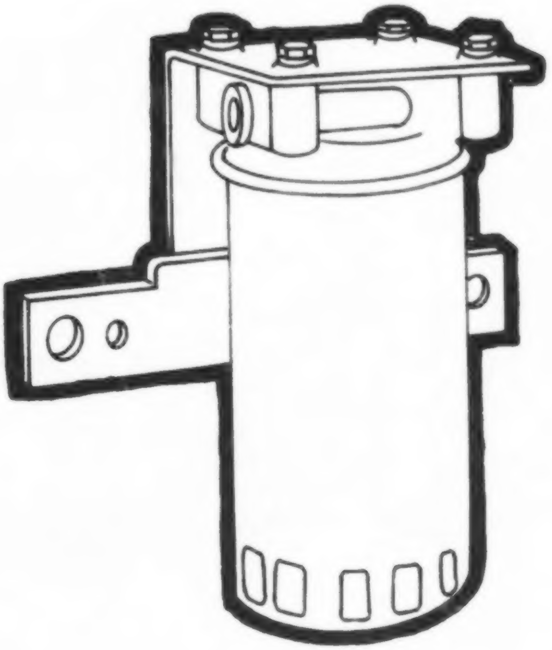
Thermostat


Sleeve Type
Seat
Sleeve
Closed
To Radiator
Primary Valve
Secondary Valve
Engine Bypass
Open
To Radiator
Primary Valve
From Engine
Secondary Valve
Engine Bypass

Visual 6.6

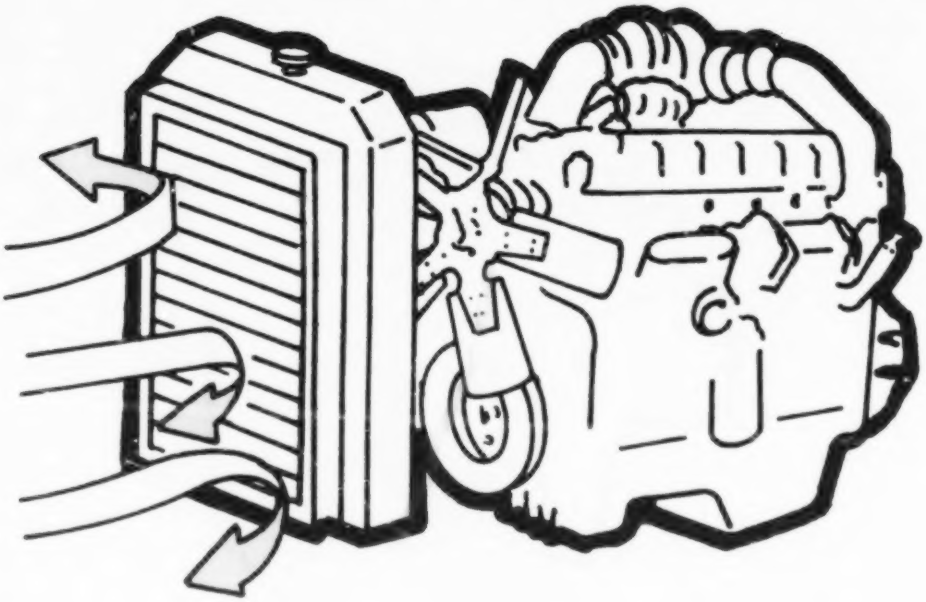
Water Filters

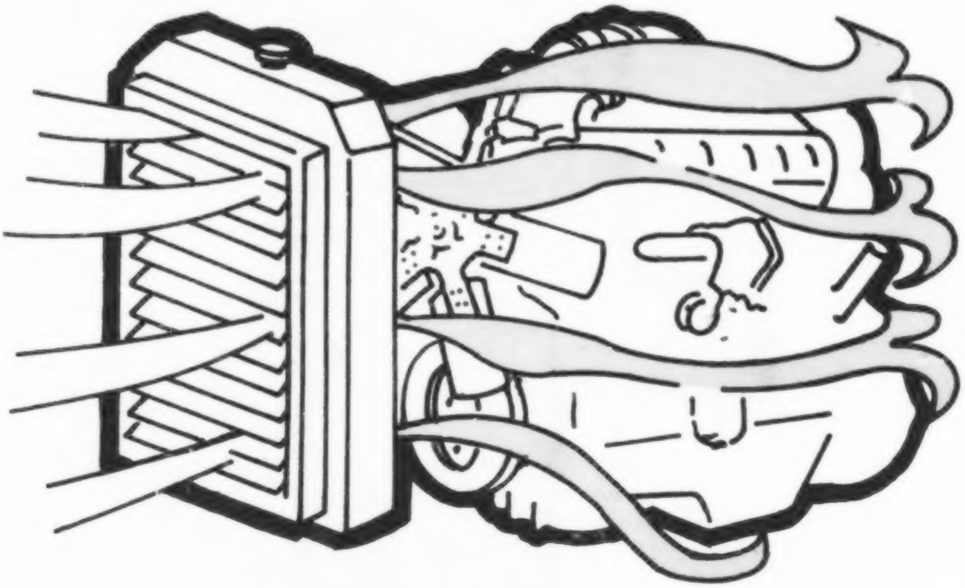

Gasket
Element
Drain Plug



Visual 6.7

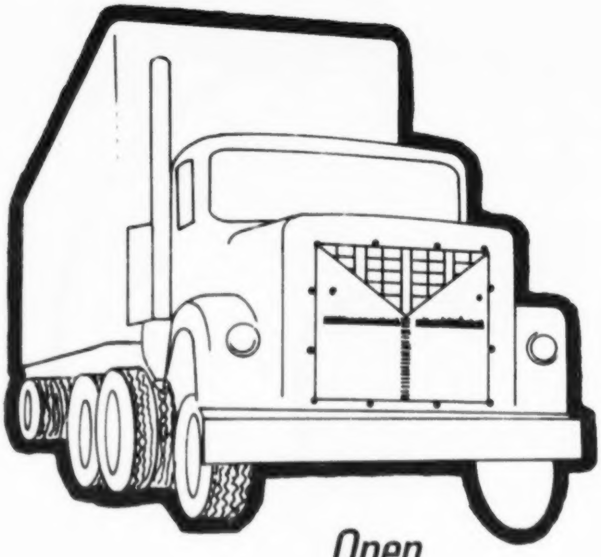
Radiator Shutters



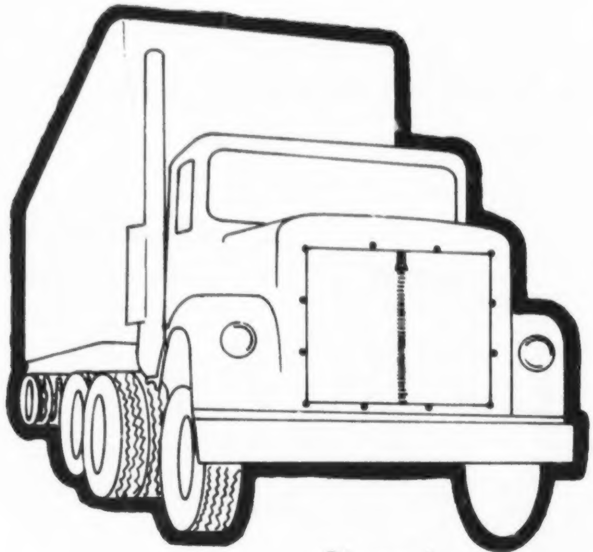


Visual 6.8

Winter Front



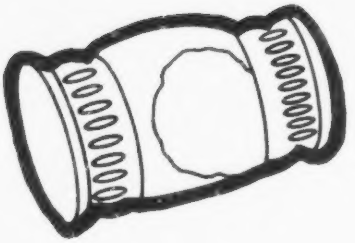
Open



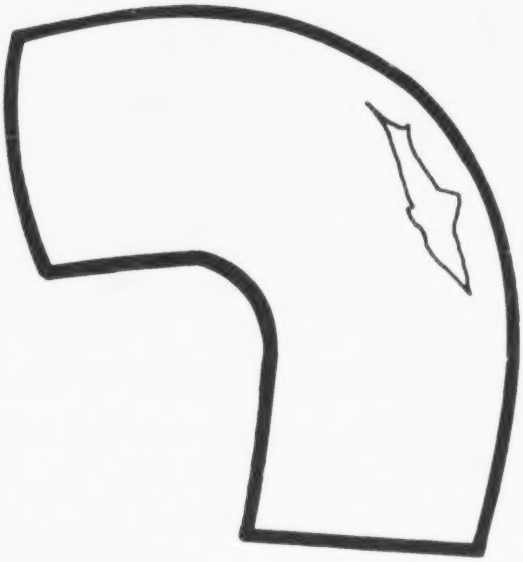
Closed

Visual 6.9

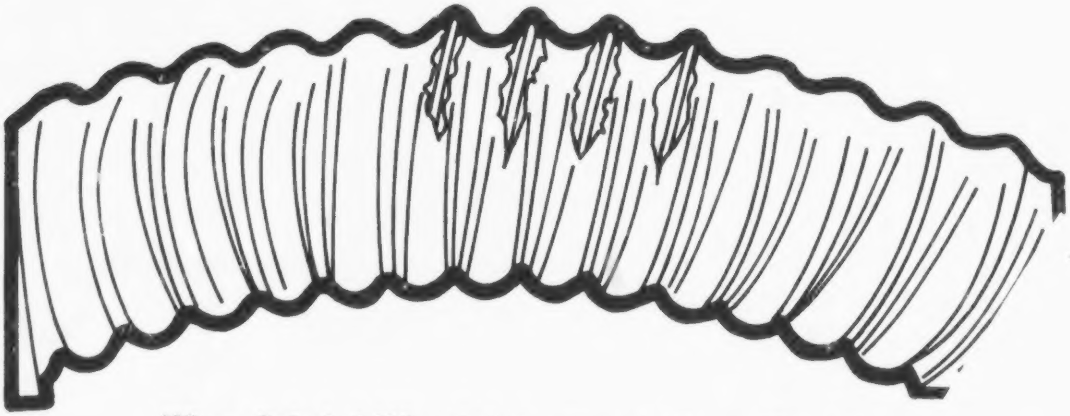
Damaged Hoses



An Oil Soaked and Softened Hose Without Wire Reinforcement Can Collapse.



Hardened and Cracked



When Spiraled Wire Reinforcement Wears Through Outer Cover, the Hose Should Be Replaced at Once.

7. ELECTRICAL SYSTEMS (1 hour 30 minutes)

Introduction

This section is provided to give students a fundamental knowledge of

- The five major vehicle electrical systems
- The major components of each electrical system, their purpose and their function
- The key role electrical systems play in safety and economy of operation by
    - Enabling the driver to see and be seen at night
    - Allowing the driver to monitor vehicle operation through instrumentation
- The nature and consequences of electrical malfunctions

Purpose

The purpose of the electrical system is to provide the power needed to

- Start the engine
- Ignite the fuel mixture (except in diesel engines)
- Provide illumination
- Run the power accessories including horns, windshield wipers, instruments
- Maintain storage batteries in a charged condition

Principles of Electricity

Briefly discuss the following electrical properties.

Current
- Refers to flow of electricity
- It is the flow of electricity that
    - Creates energy
    - Does work
- Similar to flow of water
    - Used to drive almost all mills
    - Water is still used to create electrical power (i.e., hydroelectric power from dams)

Direct Current
- Flows in one direction
- Generally generated by batteries

Alternating Current
- Flows back and forth
- House current is alternating
- Easier to transmit over long distances

Current measured in amperes or amps

Voltage
- Refers to electrical pressure
- Needed in order for current to flow
- Comes from a difference in electrical charge

    When there is a difference, electricity "wants to" flow from positive to negative.
    When connected by a "conductor," current flows.
Analagous to water pressure.
    When there is a difference in height, water wants to flow downward
    When a pipe is connected, it flows through pipe (conductor)
Voltage is measured in volts.

Resistance

Refers to opposition to electrical flow.
Most resistance comes from the electrical equipment to be powered by.
- Blowers
- Lights
- Pumps

Can also come from conductor corrosion.
Determines how fast current will flow.
    High resistance, small flow.
    Low resistance, large flow.
Analagous to water resistance.
    Mill wheels resist flow of water through spillway.
    The more work the mill wheels do, the greater the resistance, the slower the flow of water through the spillway.
Resistance is measured in ohms.

Power

Power refers to the amount of electrical energy furnished.
Indicates the amount of work that can be done.
Measured in watts.

Relationships Among Electrical Properties

Volts, Amps, Ohms
    One volt is the amount of electrical pressure needed to force one amp of current through one ohm of resistance
    Expressed as
        Voltage = current x resistance

Watts
    One watt is the power furnshed by one amp of current at one volt of resistance
        Watts = current x voltage

The terms current, voltage and resistance will be used frequently in describing electrical systems.

Components and Functions

Visual 7.1 Electrical Systems

Electrical Systems

Electrical components may be divided into the following five systems:

- Cranking system
- Ignition system
- Charging system
- Lighting system
- Auxiliary system

Cranking System

Visual 7.2 Cranking System

The purpose of the cranking system is to start the engine.

- Turns crankshaft
- Causes engine to run until fuel mixture is ignited

Cranking system consists of the following components:

- Storage battery
- Cranking motor
- Cranking switch
- Cables and wiring

Storage Battery

- Battery is the heart of the electrical system

- Stores energy for the purpose of
  - Supplying power needed to start the engine
  - Powering all electrical components when the engine is not running
  - Handling momentary electrical overloads resulting from the simultaneous use of several electrical components (e.g., lights, CB radio, heater fan)

Visual 7.3 Construction of Storage Battery

Construction of a Storage Battery

- 12-volt battery consists of six cells
- Each cell consists of the following
  - Electrolyte
    - Produces chemical reaction needed for electrical energy
    - Consists of
      - Water
      - Sulphuric acid
  - Lead plates
    - Combine with sulphuric acid to produce electrical energy
    - Carry electrical energy to terminals
  - Terminals
    - Connect to cables
    - Supply electrical energy when battery is in use
    - Receive electrical energy when the battery is charging

- Vent plugs
  - Provide a small opening for escape of gases produced by chemical reaction
  - Can be removed to permit water to be added to electrolyte
  - Not provided in sealed, maintenance-free batteries

Operation of Battery

- When battery is supplying electrical energy
  - Electrical energy is created by chemical action of electrolyte on lead plates
  - Electrical energy flows from positive terminal through the vehicle component bringing power back to negative terminal
  - As electrical energy is being discharged by battery
    - Lead sulphate forms on plates
    - Removes sulphuric acid from water
  - When sulphuric acid is exhausted
    - Current no longer flows
    - Battery is dead
- Charging
  - Battery is charged by reversing the process just described
  - Electrical current flows from alternator through battery
  - Chemical action is reversed
    - Lead sulphate transformed back into sulphuric acid
    - Supply of sulphuric acid is replenished

Size

- Size of battery measured in terms of
  - Voltage
  - Capacity

Voltage

- Determines the rate at which power can be supplied at any one moment
- Most truck batteries are 12-volts
  - Most vehicle electrical components are designed for 12 volts
  - Some vehicles connect to 6-volt batteries in series to provide 12 volts
- Some trucks have a 24-volt starting system
  - Two 12-volt batteries are provided
  - A switch allows them to be connected in series to provide 24 volts
  - Provides additional power for starting engine
  - Batteries are only connected when the cranking switch (starter button) is applied

Capacity

- Capacity refers to the total amount of power a fully charged battery can supply
- Determines the amount of time the battery will continue to supply current
- Batteries are rated in terms of ampere hour
  - Number of amperes of current the battery will supply
  - Number of hours the battery will supply it
  - Amperes x hours = ampere hours

Capacity must be great enough to crank diesel engine until it starts

Needs determined primarily by size of engine to be cranked
  - Should follow recommendations of engine manufacturer
  - Most call for batteries in the 200 amp hour

Battery Requirements

To function efficiently, batteries require
  - Electrolyte
  - Clean terminals
  - Secure connections

Electrolyte
  - Driver should check level of electrolyte frequently
  - Water evaporates over time (except in sealed batteries)
  - Loss of water limits chemical reaction and therefore power output
  - Water must be added when it is low
    - A ring in vent plug shows proper water level
    - The correct amount of water must be provided (do not overfill)

Clean Terminals
  - Corrosion can form on terminals from chemical action of electrolyte
  - Corrosion prevents good electrical connection
  - Terminals must be cleaned frequently

Secure Connections
  - Connectors can work free due to vibration of engine in vehicle
  - Must be tight to provide good electrical connection
    - Should be checked frequently and tightened as needed

Hazards
  - Primary hazard is explosion
    - Gas is generated when battery is charging
    - Can be ignited by sparks
    - Many people are blinded each year from battery explosions
    - Usually occurs when using jumper cables to start an engine
    - Proper procedure for jumping a battery will be described in Unit 4.3

Visual 7.2 (Repeat) To Show Cranking Motor

Cranking Motor

Turns the flywheel to cause the engine to turn over

Generally referred to as a starter

Construction
  - Is basically a DC motor
  - Drive shaft of motor is connected to the flywheel by a set of gears
  - Uses a high gear ratio--typically 15-to-1
    - The starter motor revolves 15 times as fast as the flywheel
    - High gear ratio needed to overcome resistance of engine

- Disconnects from flywheel
  - When engine starts, the cranking motor disconnects
    - Because of gear ratio, engine would turn cranking motor very fast (1,000 rpm engine speed = 15,000 rpm starter motor)
    - Would quickly wear out starter motor
  - As engine starts, rotation of flywheel causes gears to disengage

Air Starters

- Some vehicles use compressed air from the air tank to crank the engine
- Not really an electrical system, but most conveniently discussed here
- Operation
  - Compressed air passes over a set of vanes causing them to revolve
  - Vanes connected to drive shaft
  - Drive shaft geared to flywheel
  - Extremely simple mechanism
- Advantages
  - Can turn engine over faster on cold days
    - Low temperatures reduce battery efficiency, degrading operation of electric start
    - Cold weather does not reduce air pressure
  - Reduces weight--only one battery is needed for operation of lights and accessories
    - Reduces wear on alternator (not having to recharge battery after start)
  - Reduced maintenance due to simplicity of the starter
- Disadvantages

  - High initial cost (primarily because it is not a standard item)

Visual 7.2 (Repeat) Cranking Switch

Cranking Switch

Cranking switchs energizes the cranking motor, causing engine to turn over

Construction

- Consists of three switches
- Starter switch
  - Activated by pushing a button or toggle switch, or turning the ignition key to the start position
  - Activating the starter switch energizes the starter solenoid
- Starter solenoid
  - An electromechanical relay switch
  - When activated by the starter switch, it causes the cranking motor to turn over the engine
- Neutral "safety lockout" switches
  - Opens circuit when transmission in gear
  - Prevents cranking engine when vehicle is in gear
  - Required on or powershift type transmissions

Operation

- When starter switch is activated
  - Starter switch closes a circuit, causing current to flow through the starter solenoid
  - When current flows through the starter solenoid, it activates electromagnetic switch
  - When solenoid switch is activated, it closes a circuit allowing current to flow through the cranking motor
  - Current flowing through the cranking motor causes it to operate, turning over the engine
- When starter switch is released
  - The starter solenoid circuit is opened, interrupting the flow of current to the starter solenoid
  - When current stops flowing through the starter solenoid, the electromagnetic is de-energized, and the relay switch opens
  - When relay switch opens, it interrupts the flow of current through the cranking motor
  - When current stops flowing through the cranking motor, it stops turning over
  - When cranking motor stops, engine no longer turns over (unless it is already started)
- Purpose of solenoid
  - Heavy current needed to operate cranking motor
  - Heavy current in starter switch would create a shock hazard
  - Solenoid uses low current from starter swtich to supply heavy current to starter motor

Little servicing required

- Switch in solenoid require no servicing
  - Solenoid may fail and have to be replaced

Cables and Wiring

- Heavy cables carry current from battery through cranking motor
- Small wires carry current from cranking switch through solenoid
- Size of cable
  - Both diameter and length are designed for specific application
  - Should only be replaced by a qualified mechanic

Ignition System

Visual 7.4 Ignition System

Purpose of the ignition system is to ignite fuel mixture

- Used only in gasoline engines
- Since most tractor engines are diesel, an ignition system will be described briefly

Ignition system consists of two circuits

- Primary circuit
- Secondary circuit

Visual 7.5 Primary Ignition Circuit

Primary Circuit

Purpose is to create high voltage needed by secondary circuit

- Components
  - Electrical source
    - Battery
      - Supplies current when engine is being started
      - Already discussed as part of the cranking system
    - Alternator/Generator
      - Supplies current when engine is running
      - Will be discussed as part of charging system
  - Ignition switch--allows current to flow through the primary circuit
  - Contact points
    - Located in distributor
    - Frequently referred to as breaker points or simply points
    - Open and close as engine turns over
  - Condensor
    - Also called a capacitor
    - Absorbs current flow as contact points open
  - Ignition coil
    - Contains primary and secondary winding
    - Primary winding is between electrical source and breaker point
- Operation
  - When ignition is on, current can flow through circuit
  - Current flows each time the contact points close
  - As points close
    - Current flows through primary coil winding
    - Builds up magnetic field
  - As points open
    - Current stops flowing through primary coil winding
    - Magnetic field collapses
    - Collapsing of magnetic field creates high-voltage surge in secondary winding of coil
  - Opening and closing of contact points create high voltage for secondary circuit
  - Capacitor prevents current from jumping across contact points
    - Causes current flow in coil to stop more abruptly
    - Causes magnetic field to collapse more abruptly
    - Creates higher voltage

Secondary Circuit

Provides high-voltage spark to ignite fuel

- Components
  - Distributor rotor
    - Connected to camshaft
    - Revolves as engine turns over
  - Distributor cap
    - Center terminal

        - Maintains contact with rotor through center button
        - Button spring loaded to maintain contact as rotor turns
    - Outside terminals
        - Arranged around perimeter of distributor
        - One terminal for each cylinder
- Distributor wires
    - Carry high voltage to spark plugs
    - One distributor wire for each cylinder
    - Designed to carry high voltage
- Spark plugs
    - Has a center electrode
    - Electrode surrounded by insulator
    - Insulator surrounded by a ground electrode

Operation

- High voltage created in secondary winding of distributor by primary circuit (as described earlier)
- Current is carried from secondary winding to center terminal through coil wire
- Current flows from terminal through button to center of distributor rotor
- As rotor revolves, current is carried to each of the outer terminals in order
- Upon reaching outer terminal it is carried through high-voltage distributor wire to a spark plug
- Upon reaching spark plug it flows down the center electrode
- Upon reaching the bottom of the electrode it jumps across to ground electrode
- When current jumps a bright spark occurs
- Spark occurs just as piston reaches the top of the compression stroke
    - Causes fuel to ignite
    - Combustion forces piston down (power stroke)
- NOTE: Review briefly four-cycle engine operation as discussed earlier
- Timing of combustion determined by camshaft
    - Camshaft determines when distributor rotor will make contact with outer terminal
    - Designed to make contact at the proper time for each cylinder

Diesel Engine

- Review briefly why diesel engine requires no ignition system
    - Fuel ignited by heat from engine compression
    - No spark is required

Charging System

Visual 7.6 Charging System

Purpose

- To charge the battery
- To supply electrical energy while the engine is running

Alternator

Alternator is a device that converts mechanical to electrical energy

Components of Alternator

- Rotor
  - An electromagnet mounted on a shaft
  - Shaft is rotated by a belt connected to crankshaft
  - Hence the term "rotor"
- Stator
  - A set of wires surrounding the rotor
  - Remains stationary
  - Hence the term "stator"
- Diodes
  - Convert alternating current to direct current
  - Each diode allows current to flow in only one direction
  - In combination, diodes provide one-way flow of electricity

Operation of Alternator

- Producing alternating current
  - Each pole of the rotor creates an electrical field
  - As rotor revolves, the magnetic field from each pole cuts the stator wires
  - Magnetic field introduces a current flow in stator wires
  - As rotor continues to revolve, the two poles are reversed
  - As magnetic field from opposite poles cuts stator, the current flows in the other direction
  - Continuing rotation of rotor produces alternating current

- Rectifying alternating current
  - Alternating current must be changed into direct current
    - Vehicle components require direct current
    - Battery supplies direct current
  - Changing alternating to direct current is called "rectifying" current
  - Diodes rectify alternating current
    - Two sets of diodes are mounted in opposite directions
    - As current flows in one direction, it flows through one set of diodes to battery
    - As current flows in reverse, it flows through the other set of diodes to the battery
    - Alternating between diodes produces continuous current flow in one direction

Generator

- Also converts mechanical energy into electrical energy
- Similar to alternator except

- Magnetic field is stationary
- Wire conductors rotate within the magnetic field
  - Wire conductors are a part of the armature
  - As armature revolves it generates alternating current
  - Armature connected by belt to crankshaft

- Current must be picked off of revolving armature in order to be sent to battery
- Two brushes pick up current from armature
  - Each brush receives current in one direction only
  - The current is "rectified" in the generator itself
- Disadvatanges of generators
  - Limited current capacity
    - Brushes can only handle limited current
    - If current becomes too great, arcing (sparking) occurs
  - Wear
    - Contact of brushes with moving armature results in wear
    - Brushes must eventually be replaced
  - Alternator eliminates problem
    - Current is generated in a stationary rather than revolving component
    - Can handle more current with less wear

Voltage Regulator

A device that regulates the output of alternator or generator

- Connected to battery and alternator/generator
- When battery is low, current flows from alternator to battery
- As battery reaches maximum voltage, it resists flow from alternator
  - Increased resistance causes voltage in alternator to rise (to overcome resistance)
  - This causes current to flow through the regulator
  - When the alternator voltage reaches a peak, current in the regulator closes a contact
  - Closing this contact causes a reduction of current through the alternator windings, resulting in a voltage drop
  - When the alternator voltage drops, the voltage regulator contacts open again, allowing alternator voltage to climb
  - The cycle is repeated hundreds of times a second to keep the alternator output at the appropriate level
  - Newer solid state voltage regulators use transistors instead of electromagnetic contacts

Charging System Requirements

- Alternator, generator, and voltage regulator do not generally require servicing
- Drive belts must be properly tensioned

  - Too loose
    - Slippage
    - Result in
      - Excessive belt wear
      - Inadequate charging
  - Too tight
    - Puts strain on bearings
    - Can cause bearings to burn out

Visual 7.7 Electrical Gauges

Electrical Gauges

Two gauges register the operation of the charging system

Ammeter
Volt meter

Ammeter

- Measures flow of current through the charging system
- Readings
  - Charge or "+"
    - Battery is charging
    - Very slight charge at cruising speeds is normal
    - Strong charge right after starting or when battery has been drained is normal
    - Continued strong charge is not normal
  - Discharge or "-"
    - Battery is discharging
    - Normal when electrical equipment is in use and engine is off or running very slowly
    - At cruising speed, indicates defective alternator or regulator
  - In "0" position
    - Normal when ignition is turned off or operating at cruising speed with fully charged battery
    - If needle never leaves the zero position, even when the battery has been discharged (e.g., starting) alternator or regulator is defective

Volt Meter

- Measures the voltage available from the battery
- Readings
  - 13.5 to 14.0--normal
  - 12.0 to 13.5
    - Normal if battery has been drained
    - Abnormal if continues
  - Less than 12.0 or over 14.5--abnormal; charging system should be checked

Ignition Requirements

For proper performance, ignition system requires maintenance

Spark Plugs

- Most vulnerable of ignition parts to deterioration
- Dirt
  - Insulator
  - Mixture of dirt, carbon, oil, moisture
  - Forms a conductor that shorts out the spark plugs
  - Needs to be wiped clean when dirty
- Fouling of electrode tip
  - Results from
    - Improper gas mixture
    - Poor quality fuel
    - Improper ignition timing

- Reduces spark
- Results in incomplete combustion
- Requires replacement of plug
- Cracking
  - Results from overheating, carelessness
  - Requires replacement

Distributor

- Contact points
  - Become pitted over time
  - Must be replaced periodically
- Condenser
  - Deteriorates in time
  - Generally replaced with contact points
- Cap and rotor
  - Wear down eventually
  - Can be replaced
- Timing
  - Requires periodic adjustment (tune-up) so that spark occurs at the right time
  - Improper timing results in
    - Poor mileage
    - Fouled spark plugs

Lighting System

Lighting system furnishes power to vehicle lights

Kinds of Lights

- Headlights
- High-beam indicator
- Clearance lights
- Identification lights
- Identification instrument panel lights
- License plate lights
- Tail lights
- Stop lights
- Driving lights
- Turn signal lights
- Hazard warning lights
- Dome lights
- Backup lights
- Parking lights
- Trailer lights (clearance, identification, etc.)

Components

Lighting system consists of the following types of components

- Wires and cables
- Connectors/adapters
- Resistance boxes
- Junction boxes
- Circuit breakers
- Lamps

Wires and Cables

- Each wire or cable is designed for specific application
- Design characteristics
  - Types of wire
    - Referred to by "gauge" (diameter)
    - Determined by
      - Amount of current to be carried
      - Flexibility needed
  - Insulation--size and material determined by:
    - Amount of current
    - Needed flexibility
    - Exposure to elements
  - Color
    - Some wires are color coded for easy identification
    - Placement must be made with the same type of wire
  - Several wires may be combined in one cable
    - Simplifies installation
    - Protects individual wires
  - Harnesses
    - Two or more wires or cables bound together
    - Prevents snagging

Visual 7.8 Connectors

Tractor-Trailer Electrical Connectors

- Connect power source of tractor to the trailer

Plugs

- Portion of the connector that is "hot" (is connected to the electrical source)
- Wire contact points are recessed into plug
  - To guard against electrical shock
  - Prevents contact with surfaces resulting in short circuit

Receptacle

- Usually has a set of contacts (prongs) that insert into the plug
- Contacts are generally recessed to receptacle housing to prevent damage
- Many receptacles are grounded to reduce shock hazard
- Most receptacles have a hinged cover to protect contacts when receptacle not in use

Connection

- Most plugs and receptacles are designed so they can only be connected one way
  - Through irregular pattern of contacts
  - Through different size contacts
  - Through a "key" that prevents connection unless plug is properly aligned

Adapters

- Allow one type of plug to be connected with a different type of receptacle
- Usually a cable with one type of plug and another type of receptacle
- Internal wiring makes the proper connections

Resistance Devices

- Devices that transform voltage
- Usually used to connect 12-volt sources to 6-volt lighting systems

Junction Boxes

- Allows one cable to be connected with two or more other cables
- Mounted on vehicle

Fuses and Circuit Breakers

- Devices that interrupt the flow of electricity when there is an electrical overload
  - Short circuit
  - Excess of voltage
- Fuses
  - Overload causes wire to melt
  - Melting wire interrupts circuit
  - Must be replaced to provide connection
- Circuit breakers
  - Electromagnetic switch opens circuit during overload
  - Switch closes when overload ceases
    - Protects lighting equipment (or accessories) from damage due to overload

Lamp

Visual 7.9 Headlamp

- Headlights
  - Basic design
    - Filament--lights up to provide illumination
    - Reflector--reflects all of the light from the filament in one direction
    - Lens--focuses a beam of light
  - Type I--has only one filament
  - Type II--has two filaments
    - One for high beam
    - One for low beam
  - Type I headlight can only be used along with Type II headlights in order to allow dimming
- Stoplight
  - Light consists of filament, reflector, and lens
  - Operated by a switch connected to the service brake pedal (treadle valve)
- Exterior lights
  - Clearance lights, identification lights, tail lights, hazard warning lights, etc.
  - Use white or colored lenses (red, amber) for proper color
  - Basic design is usually similar to minimize the number of parts that need to be stocked
  - Lenses must be replaced with same color to meet state and federal regulations

READEX FICHE

- Warning lights Lights mounted in dash to warn of dangerous condition, e.g., low oil pressure
  - Light is connected to some form of sensor which closes a switch when dangerous condition arises

Lighting Circuit Requirements

Number of conditions can reduce the effectiveness of lighting

- Poor contact
  - Loose connection, moisture, or corrosion can prevent good contact
  - Connectors need to be inspected and cleaned
- Cabling
  - Poorly secured cabling can drag, snag, rub, abrade, bind, or otherwise be exposed to damage
  - Must be of proper length and secured through harnessing where necessary
- Insulation
  - Can suffer from cracks, abrasion, cuts
  - Allows leakage of current and short circuits
- Lenses
  - Dirt can lower illumination
    - Unsafe
    - Fail to meet requirements set by law

- Lenses
  - Dirt can lower illumination
    - Unsafe
    - Fail to meet requirements set by law

Auxiliary System

Provides power to electrical accessories

Components

- Motors
  - Heater and defroster fan
  - Ventilating fan
  - Windshield wiper
  - Roof condensor
  - Window lift
- Pump
  - Fuel Pumps
  - Windshield washer
- Electric fuel heater
- Horn
- Fuel shutoff

Temperature, fuel, etc.

Operation

Distribution of electricity (wiring, cables, connectors, etc.) are the same as described in lighting system

The major differences is in the operation of the electrical accessories themselves

- This is not of course in vehicle accessories
- Operation of accessories will only be breifly described

Motors

- Used to power fans, blowers, windshield wipers, etc.
- Operate in the same general manner as the starter motor
  - Components
    - Armature
      - Rotating shaft connected to fan or blower
      - Wires in armature set up a magnetic field
    - Field windings
      - Wires surrounding the armature
  - Operation
    - Current flows through armature and field windings
      - Sets up magnetic fields
      - One field repels the other
    - Causes the armature to revolve
      - Supplies rotary motion to power fans
      - In windshield washer
        - Rotary motion is converted to back-and-forth motion
        - Reverse of the way a crankshaft operates
        - (Instructor can illustrate with one arm)

Gauges

- All gauges function in the same general fashion
  - Consist of a sensor and indicator
  - Sensor
    - Usually consists of a resistor
    - Resistance varies with change in condition (to be described in a moment
    - Change in resistance regulates flow of current to the indicator
    - EXAMPLES: Fuel gauge
      - A float in the tank is attached to a variable resistor (like volume control on radio)
      - Causes resistance to change as the float rises and falls (with level of fuel)
    - Temperature gauge
      - Heat-sensitive element (thermistor) is immersed in water
      - Resistance changes with heat
    - Oil pressure gauge
      - Pressure pushes up on diaphragm
        - Diaphragm is connected to a variable resistor
        - Resistance changes as diaphram goes up and down
  - Display
    - Consists of a pointer between two electric coils
    - Coils connected to sensor
    - As current flows through the coil, it creates a magnetic field
    - Magnetic field deflects the position of the pointer
      - Position of pointer corresponds to resistance of sensor to indicate condition (amount of fuel, water temperature, oil pressure)
  - Gauges require fine adjustment to give accurate readings
  - Can give false readings due to:
    - Misadjustment of gauge
    - Changes in resistance due to moisture, aging of parts, etc.

Changes in resistance due to moisture, aging of parts, etc.
Driver must not rely totally upon gauges

Pumps

Almost all small electric pumps are diaphragm pumps
Windshield washer and electric fuel pumps work in the same manner
- Components
  - Armature
  - Springs
  - Bellows
- Operation
  - When electromagnetic is energized, it pulls down the armature
  - When armature is pulled down, it pulls a diaphragm or bellows down
  - Pulling down diaphragm creates partial vacuum
  - Partial vacuum draws fluid down through inlet valve (also pulls outlet valve closed)
  - When armature reaches bottom it disconnects the electromagnet
  - Spring forces diaphragm back up
  - Fluid is forced out of the outlet valve (inlet valve is force shut)
  - Cycle repeats itself several times a second
  - Causes a continuous flow of fluid
    - Fuel pump--forces fuel to carburetor or fuel injector
    - Windshield washer--squirts water on windshield

Horn works in the same general way

Metal plate moves up and down instead of diaphragm
Contact of metal plate with housing produces sound

Locating and Recognizing Problems

Inspection

During vehicle inspection, it is vital that the drivers check for:
- Any lights that may be out
- Any broken, worn, frayed or badly abraided wiring
- Loose wiring hanging down that may be caught by road debreis or have snow and ice buildup
- Loose connections on electrical cable from back of tractor to nose of trailer
- Electrical cable not properly supported by either the provost stick or the hose tenders at the back of the cab
- Battery cables and connections tight and free from corrosion
- Battery electrolyte level
- Condition of cable and cable connection points

Operation

In cranking engine
- Release starter switch after 10 seconds

- Allow to cool down for at least 30 seconds before attempting to start again
- Observe the ammeter when the engine is being cranked
  - If there's a small leaning of about two amps which fluctuates regularly while cranking them, it's likely that the primary circuit is working properly.
- If the ammeter shows a rather high and steady discharge reading without fluctuation during cranking, there is a problem with an open circuit

After the engine starts, watch the volt meter or amp meter (depending on how vehicle is equipped)
- It should show charge for a period of time
- After that, it should go to neutral ("0" on the scale)

Periodically monitor volt meter or amp meter to determine conditions of overcharging or undercharging

Many fleets adjust the outmotors and voltage regulators to minimize battery charging during warm summer months.
- During the first periods of cold weather, may not have been readjusted
- Driver could expect a hard starting problem or dead battery

Drivers should
- Learn whether the vehicle is equipped with positive or negative ground
- Learn how for purposes of knowing how to jumpstart battery

Driver should also consult the Operator's Manual before jumpstarting battery (this will be discussed in detail in a later section).

Post-Trip Inspection

Report any electrical system malfunctions promptly whenever they occur.

Recap

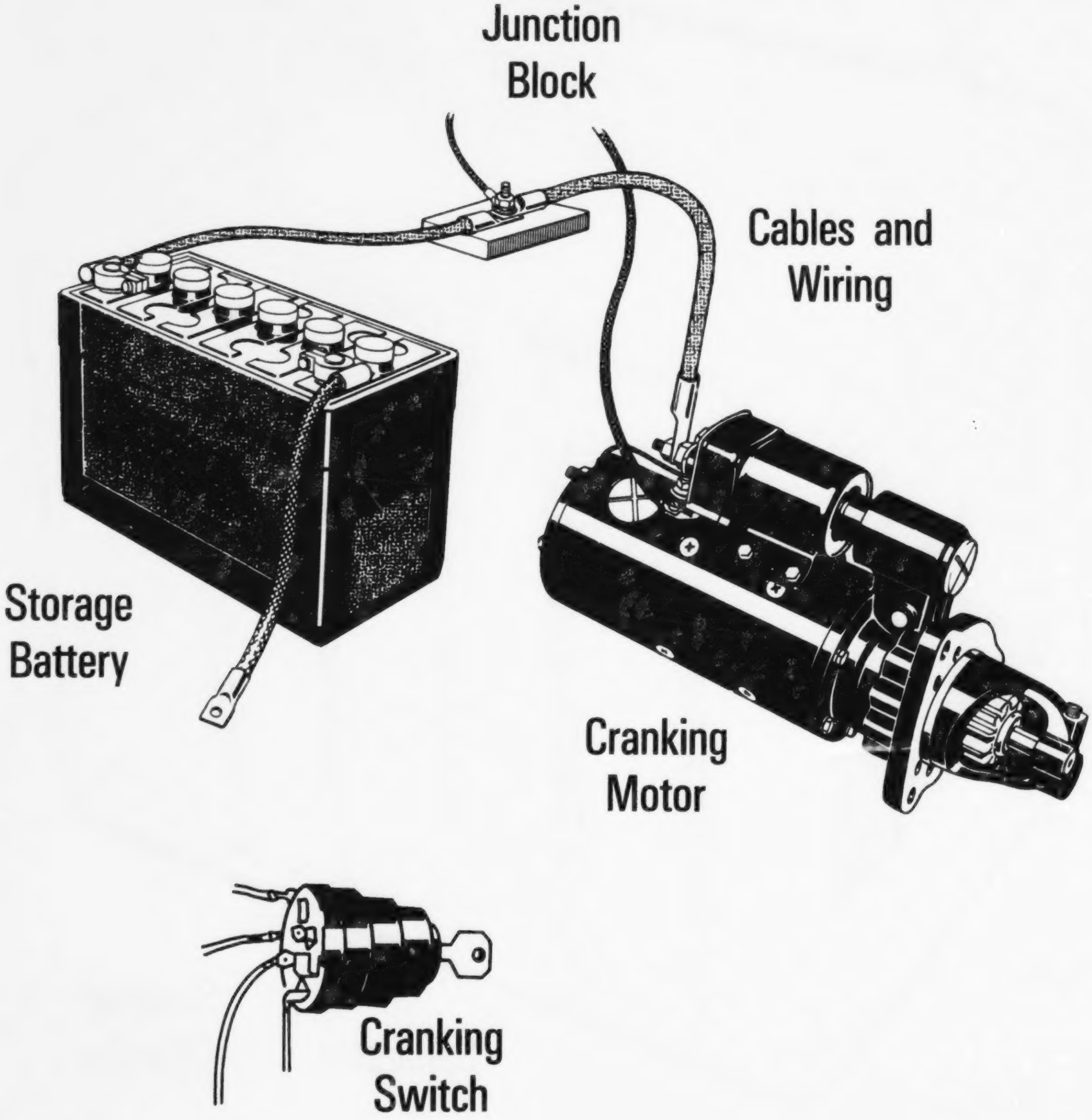
Electrical system is one of the most important
- Used for lighting, for communication, for monitoring the condition of other vehicle systems, etc.
- Taken for granted by everyone, drivers and mechanics included
- Most people lack understanding of it
- Accounts for the fact that it is one of the most frequent causes of vehicle roadside failures
- Roadside failures frequently result in severe accidents especially if they occur at night and the lighting system fails
- Professional drivers should take it upon themselves to learn all they can about electrical systems and how they function, including
  - Cranking system
  - Ignition system
  - Charging system
  - Lighting system
  - Auxiliary system
- All electrical systems should be carefully and thoroughly checked during pretrip and post-trip inspections
- In particular, the lighting system during problems with electrical systems should be noted and promptly reported to the supervisor

5 Electrical Systems

- Cranking System
- Ignition System
  (Gasoline Engines Only)
- Charging System
- Lighting System
- Auxiliary System

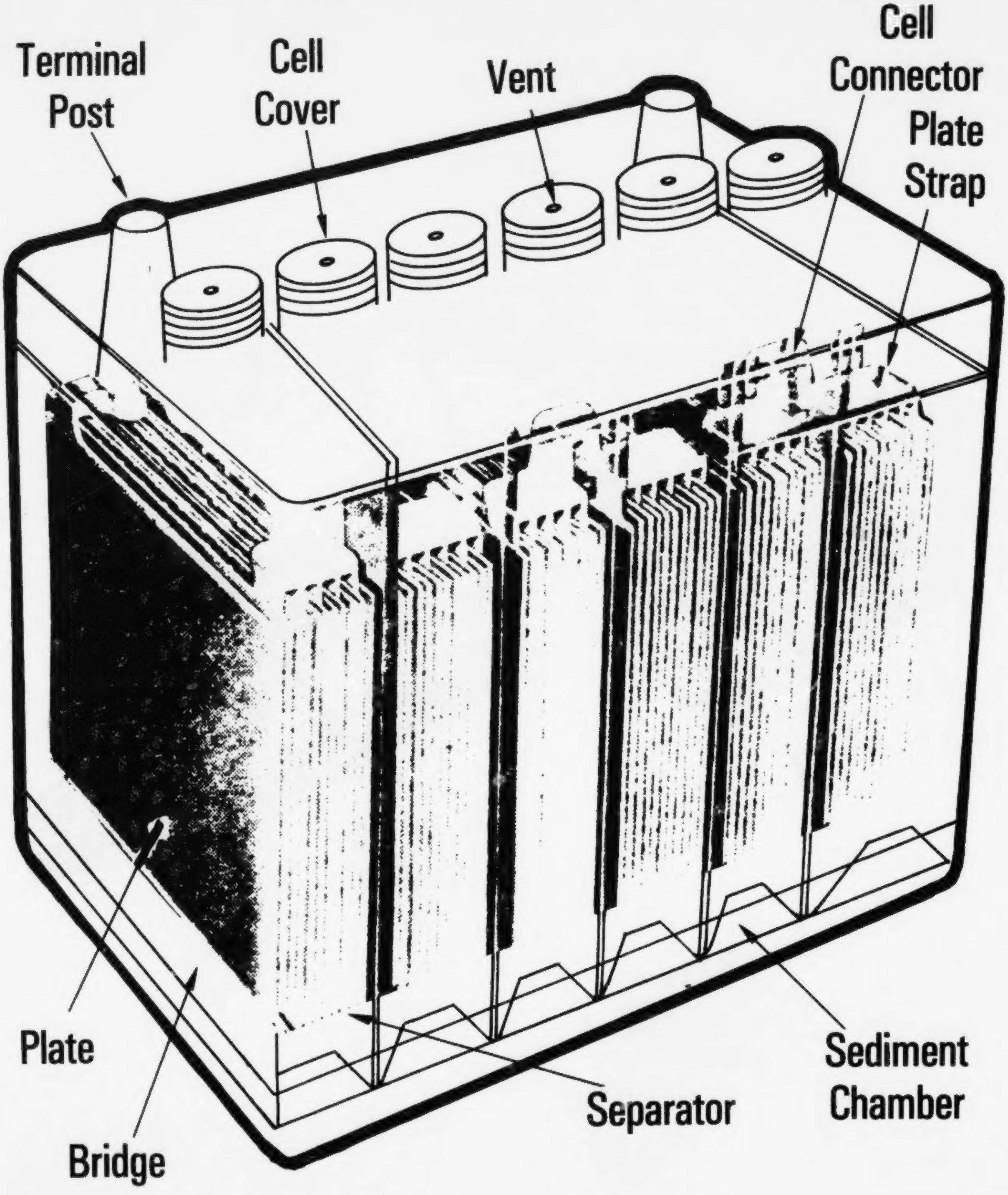
Visual 7.2

Cranking System


Junction Block
Cables and Wiring
Storage Battery
Cranking Motor
Cranking Switch

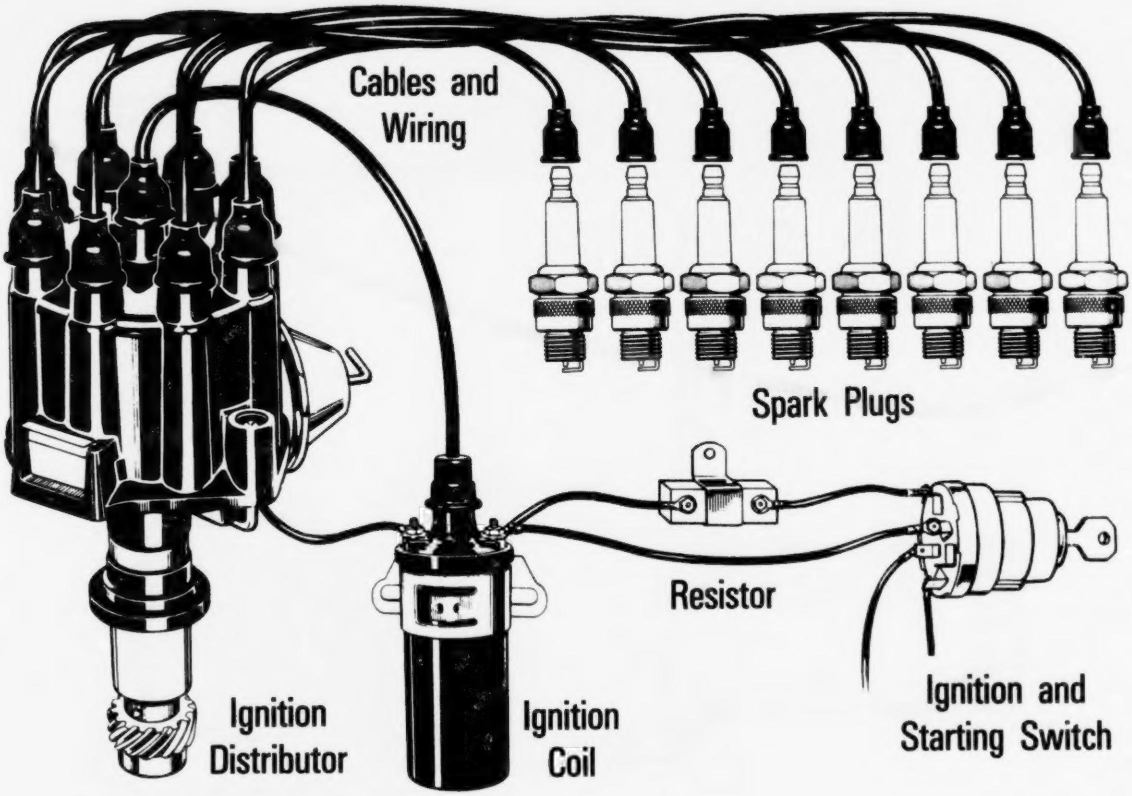
Visual 7.3

Construction of Storage Battery


Terminal Post
Cell Cover
Vent
Cell Connector
Plate Strap
Plate
Bridge
Separator
Sediment Chamber

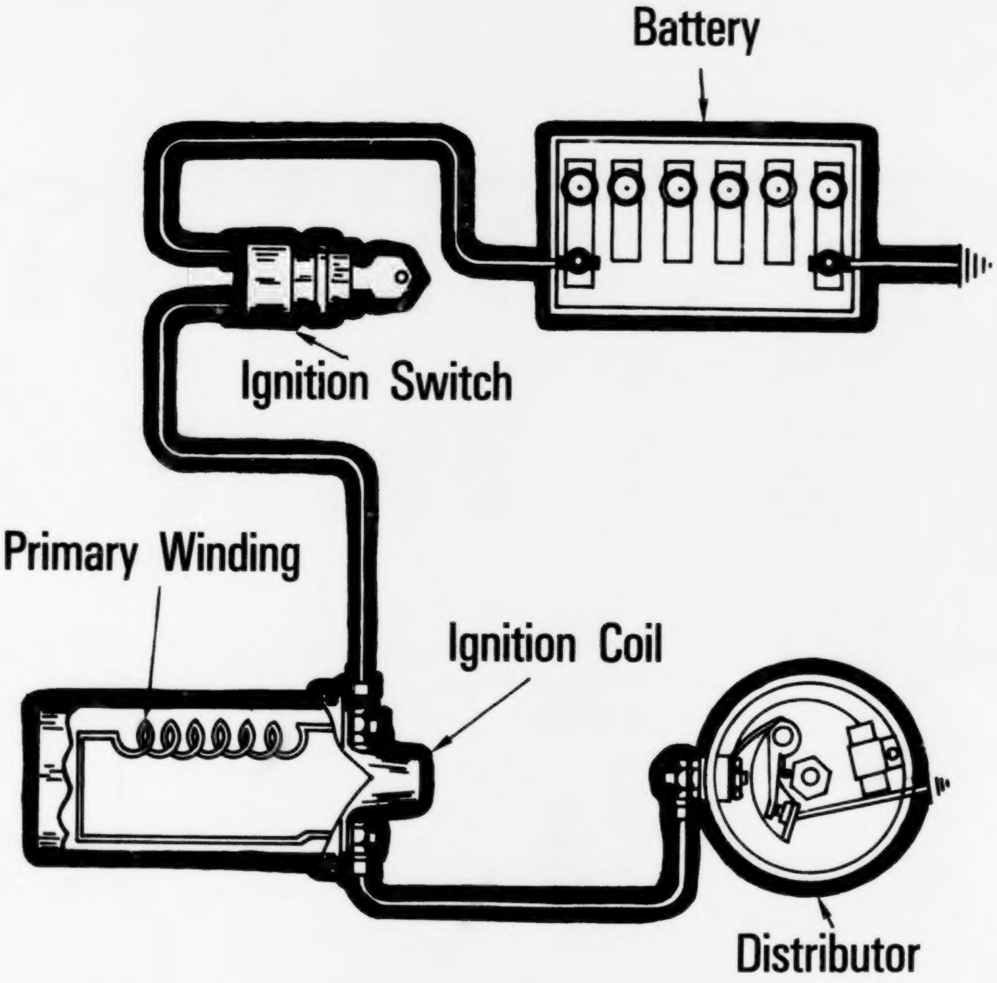
Visual 7.4

(Gasoline) Ignition System


Cables and
Wiring
Spark Plugs
Resistor
Ignition and
Starting Switch
Ignition
Distributor
Ignition
Coil

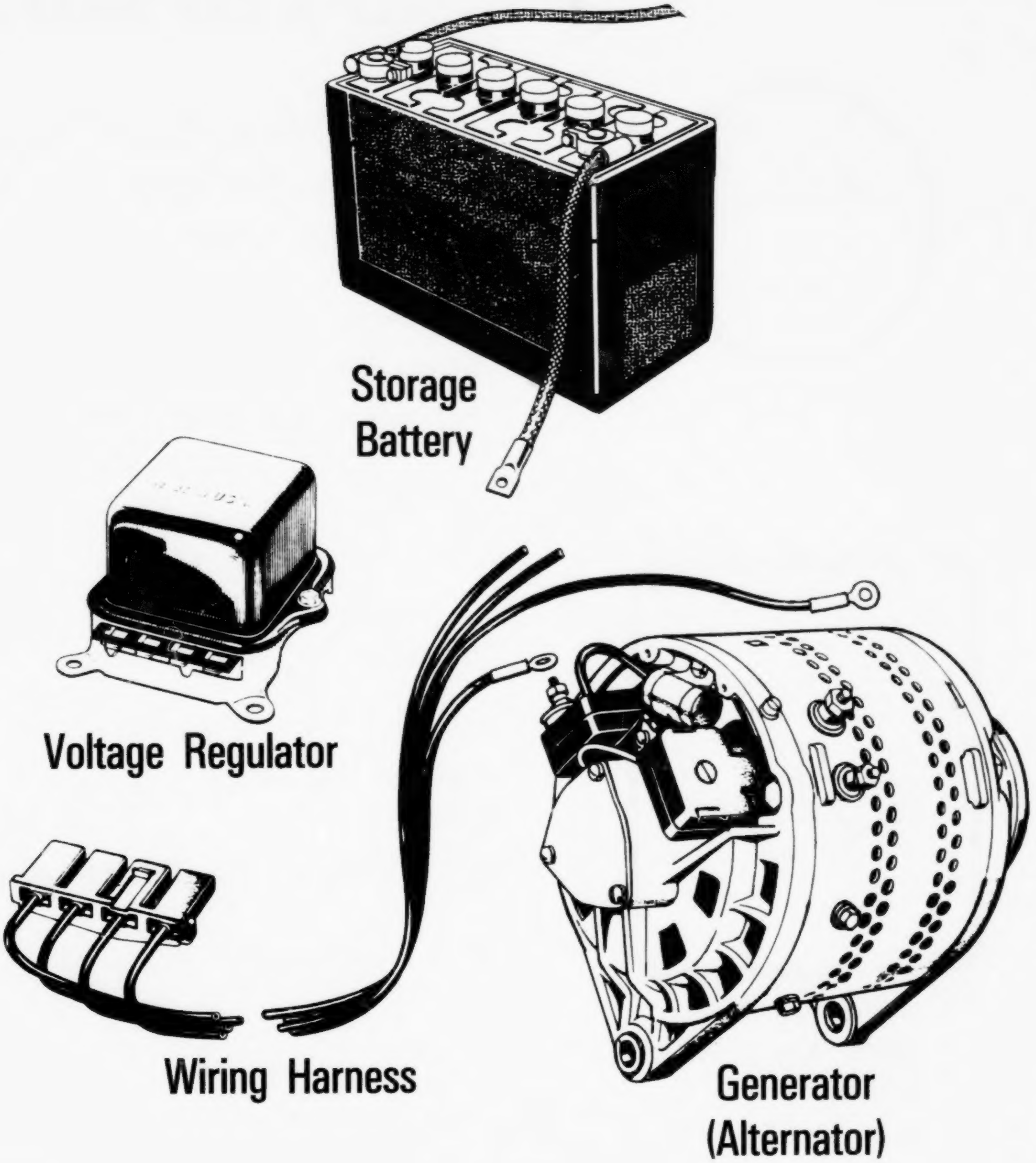
Visual 7.5

Primary Ignition Circuit


Battery
Ignition Switch
Primary Winding
Ignition Coil
Distributor

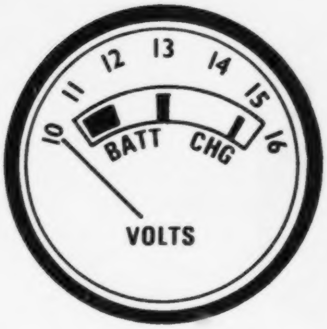
Visual 7.6

Charging System


Storage Battery
Voltage Regulator
Wiring Harness
Generator (Alternator)

Visual 7.7

Electrical Gauges


10
11
12
13
14
15
16
BATT
CHG
VOLTS

Voltmeter (In Some Models)

Starting

Green–Well Charged Battery

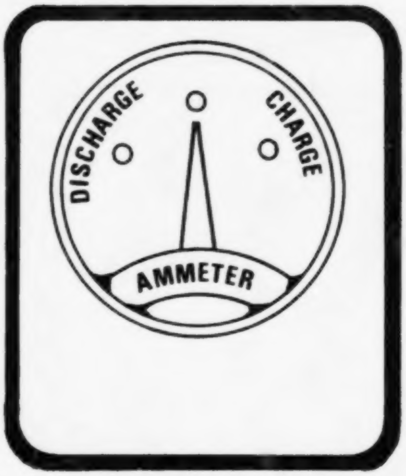
Yellow–Low Battery Charge

Red–Very Low Charge

Operating

Green–Okay

Red–Voltage Output Too High!


DISCHARGE
CHARGE
AMMETER

Engine Shut Down.
Ignition Key in Off
Position.

Ammeter

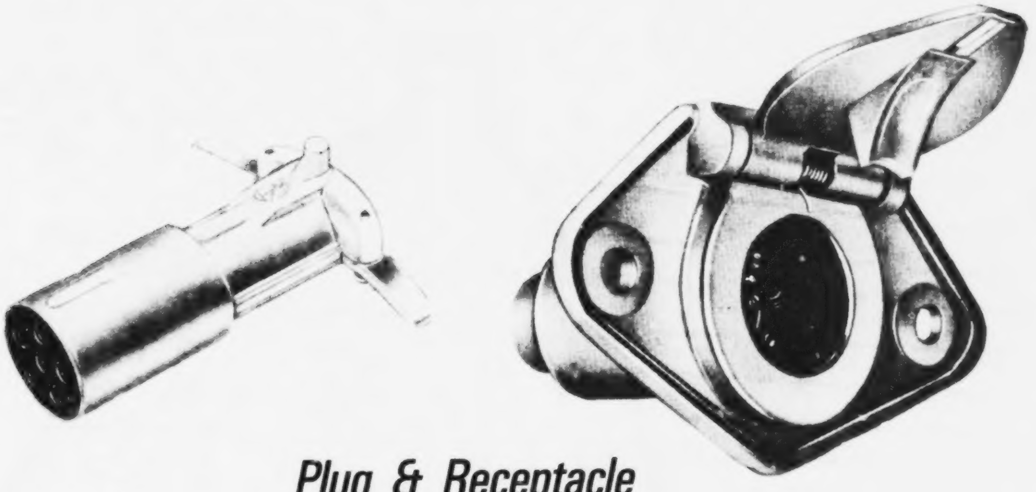
Normal Is "Zero"

Continuous High Charge + or Discharge –

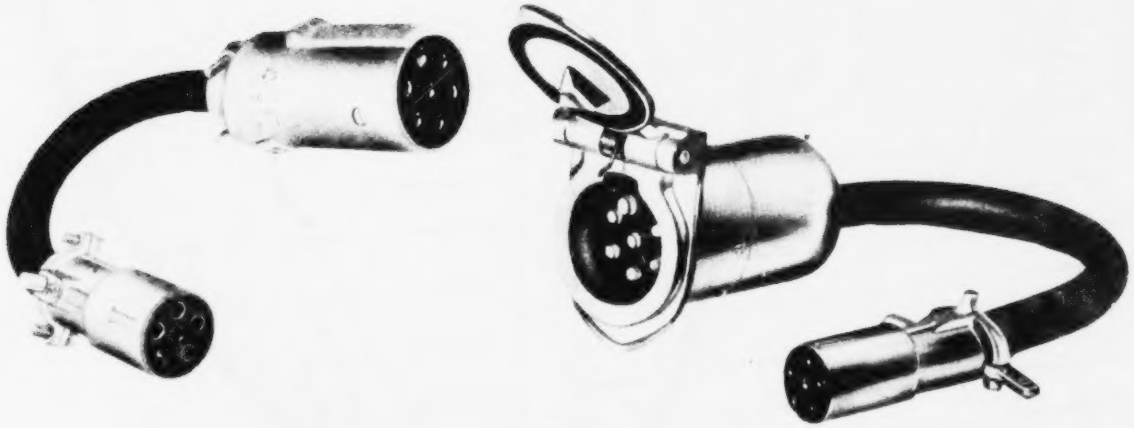
Means Problems in the Electrical System

Visual 7.8

Tractor-Trailer Electrical Connectors



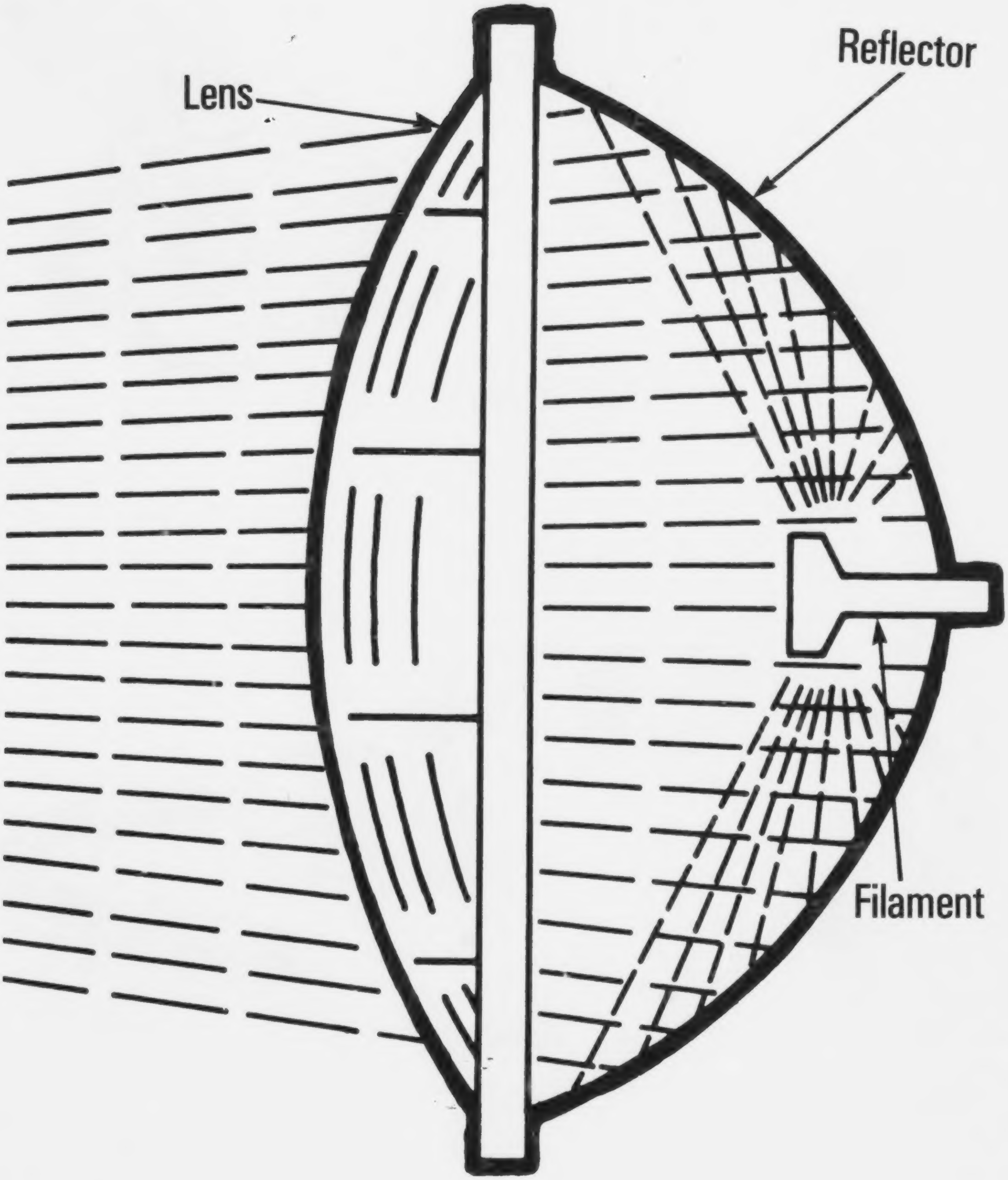
Plug & Receptacle



Adaptor

Visual 7.9

Headlamp


Reflector
Lens
Filament

8. DRIVE TRAINS (1 hour 15 minutes)

Introduction

This topic has been designed to give students a fundamental knowledge of
- How power is transmitted
  - From engine to rear axle(s)
  - From rear axle to drive wheels
- How gears are used to increase or decrease
  - Speed
  - Torque
- Some of the more common types of main and auxiliary transmissions
- The effect of gear arrangements upon speed and power, and the effect of these, in turn upon economy and safety of operation.

Purpose

Drive train transmits engine power to drive wheels of tractor
- At various speeds
- In the desired direction
- At required torque

Can operate other pieces of equipment outside of tractor-trailer, using power take off, such as
- Hydraulic lift pumps (to raise trailer)
- Winches

Basic Drive Train

Visual 8.1 The Drive Train

Briefly review the drive train components as follows

Clutch

Connects and disconnects engine from the rest of the drive train
- To shift gears
- To idle engine without shifting gears into neutral
- To start engine without causing transmission to turn (e.g., cold weather starting)

Transmission

Changes the power-speed relationship available from engine at any engine speed
- Low gear--high power, low speed
  - Accelerating vehicle
  - Driving up hills
- High gear--more speed, less power
  - Cruising speed
- Changes the direction of drive train motion
  - Forward
  - Reverse

Drive (Propeller) Shaft

Transfers power from transmission to drive axle
Has universal joint at each end to allow drive shaft to operate at different angles

Differential

Transfers power from drive shaft to a front or rear powered axle
Allows drive wheels to turn at different speeds
  Necessary when vehicle is turning a corner
  Outside wheels must travel faster than inside wheels (because they travel a longer distance)

Driven Axle

Transfers power from differential to wheels
The final link in the drive train

Clutch: Components and Functions

Function

Disconnects engine from rest of the drive train or
  shifting gears
    Power must be removed when shifting between gears
    Gears will not mesh (without damage) if power is still supplied
  Allow engine to idle without being in neutral
    At stop lights and stop signs
    Avoids having to shift into gear when it's time to move
  Allows starting without causing transmission to turn
    Even in neutral, transmission gears resist movement of crankshaft
    In cold weather, can be difficult to start engine

Visual 8.2 Clutch Location

Clutch Location

Clutch is located just behind engine, between the engine and transmission

Visual 8.3 Clutch Components

Clutch Components

The clutch assembly consists of eight parts

Clutch Pedal
  Driver control pedal in cab
  Allows driver to operate clutch

Linkage
  Consists of rods, levers, or cables
  Carries movement of clutch pedal to release bearing

- Clutch Fork
    - Holds release bearing on one end
    - Provides place for clutch linkage to connect on other end
    - Sticks out of clutch housing

- Release (throwout) Bearing
    - Slides back and forth moving release levers (fingers)

- Release Levers
    - Pivot on eye bolts
    - Are either pushed or pulled by release bearing
    - Motion is carried by struts to pressure plate

Visual 8.4 Pressure Plate and Cover Assembly

- Pressure Plate and Cover Assembly
    - Provides housing for clutch
    - Is bolted to flywheel

- Springs
    - Located between cover and pressure plate
    - Creates grear pressure against pressure plate
    - Number and size vary depending upon type of clutch

- Pressure Plate
    - Applies pressure to clutch disk
    - Is a driving plate

Visual 8.5 Clutch Disks

- Clutch Disks
    - Also called a friction disk or driver plate
    - Is mounted on transmission input shaft
    - Disk consists of
        - Splined hub
            - Center of disk
            - Internal teeth of hub match and interlock with
            - External teeth of input shaft
            - Connects clutch with transmission
        - Plate
            - Surrounds hub
            - Cushion springs and disk facings are attached to it
        - Cushion springs
            - Attached to plate
            - Clutch facings are attached to springs
            - Springs are waved or curled slightly
            - As clutch is engaged, springs compress absorbing shock of engagement
        - Facings
            - Mounted on cushion springs
            - May be made of
                - Woven asbestos
                - Organic material
                - Ceramic buttons

  - Must have a high tolerance for heat
  - Clutch disk is clamped between flywheel and pressure plate
  - Facings create functions as they are pressed against flywheel, causing
    - Disk to rotate
    - Power to be transferred to transmission
- Dampening springs
  - Set in a circle around hub
  - Are spiral in shape
  - Help smooth out power pulses from engine
  - Creates smooth power flow to transmission

Clutch Operation

- Clutch Disengaged
  - Driver depresses clutch pedal
  - Clutch linkage transfers clutch pedal motion to clutch fork
  - Clutch fork forces release bearing inward
  - Release bearing pushes or pulls against release lever
  - Release lever carries movement to pressure plate, compressing springs with springs compressed
    - Pressure is taken off clutch disk
    - Space appears between disk, flywheel and pressure plate
    - Flywheel can rotate without sending power through friction disk
    - Clutch disengaged

- Clutch Engaged
  - Driver releases clutch pedal
  - Pressure is taken off release bearing
  - Springs push pressure plate against disk
  - Disk is again clamped tighly between flywheel and pressure plate
    - Disk must rotate with flywheel
    - Engine power is transferred from flywheel to transmission
    - Clutch engaged

Types of Clutches

Push Type Clutch

- Clutch released (disengaged) by
  - Throwout bearing pushing release levers toward engine flywheel

Pull Type Clutch

- Throwout bearing is pulled away from engine flywheel

Wet Clutch

- Clutch parts are fully bathed in a lubricant
  - Fluid from the transmission is drawn into the clutch
    - Lubricates disk facing as well as other clutch parts
    - Dissipates heat created by clutch operation
- A wet clutch offers
  - Simpler maintenance--no greasing is necessary
  - Longer life--cushioning effect and cooling qualities of oil allow parts to last longer

Dry Clutch
- Clutch parts are not bathed in oil
- Must be greased periodically

Mechanical Clutch
- Mechanical linkages (as described earlier) consisting of rods and levers transfer motion of clutch pedal, to operate clutch

Air and Hydraulic Clutches
- Used in vehicles where clutch is located far from clutch pedal
- Instead of using a complicated linkage between clutch pedal and clutch, an air or hydraulic device is used
- Air pressure or hydraulic fluid moves release bearing (through a push rod) operating clutch

Multiple Disk Clutch
- Some heavy duty clutches have two or more clutch disks and pressure plates
- EXAMPLE: Dual disk clutch assembly (components)
  - Pressure plate and cover assembly
  - Rear (driven) disk
  - Intermediate drive plate
  - Front (driven) disk
  - Flywheel
- The additional plate(s) and disk(s) give more frictional surface for clutch to transmit engine power
- Many heavy duty tractors which pull very heavy loads are equipped with a multiple disk clutch

Clutches Equipped with a Clutch Brake
- A simple friction disk brake is located on transmission input shaft between
  - Release bearing housing, and
  - Front of transmission
- When clutch pedal is depressed beyond disengaged point (all the way to floor) release bearing housing contacts brake disk
- Braking force slows input shaft and attached gears
- Allows for easy shifting into first or reverse

NOTE: Clutch brake should never be used when vehicle is in gear or moving--by doing so, clutch brake is used to slow the entire rig.

Visual 8.6 Clutch Free Travel

Manually Adjusted Clutches
- As clutch disk facings wear
  - Amount of clutch pedal "free travel" is reduced
  - Slippage and finally failure will result
- Unless there is some "free travel" between release bearing and release levers, clutch
  - Will not be fully engaged when clutch pedal is retracted
  - Release bearings, pressure plate levers and clutch facings will soon fail

There are two types of clutch adjustments normally performed

- Internal adjustments--pressure plate is adjusted to compensate for disk facing wear

Visual 8.7 Linkage Adjustment

- Linkage adjustment--adjustment nut(s) on linkage assembly are tightened to adjust clutch pedal "free travel"
- Clutch pedal "free travel" can be used as a guide to conditions inside clutch
- External linkage
  - Should not be adjusted to compensate for internal clutch wear
  - Should only be adjusted to provide proper "free travel" of clutch pedal after internal adjustments have been made
- Self-adjusting clutches
  - Clutch automatically repositions clutch release bearing as disk facings wear
  - This maintenance
    - Required clearance between release bearing and levers
    - Required clutch pedal "free travel"
  - No linkage adjustments are needed

Transmission: Components and Functions

Function

To understand the function of the transmission, must first understand torque or twist and its relationship to speed

- Torque vs speed
  - Power comes out of engine in the form of twist or torque
    - Torque and speed are both related to engine power
    - A transmission, through the use of gears, allows a driver to vary the amount of torque the engine delivers to the rear wheels
    - Because of the transmission
      - The more turning effort or torque transmitted to the wheels, the slower the vehicle will move
      - The faster the vehicle moves, the less torque delivered to the wheels
    - Speed and torque are inversely related

Visual 8.8 Operation of Gears

Operation of Gears

Transmission consists of a long metal box filled with different size gears

When the transmission is in gear, two gears are engaged (connected to one another)

  - One gear is connected to the engine
    - Connected to the crankshaft through the flywheel
    - Will refer to it as the "drive" gear
      - It is connected to the source of power
      - Drives the other gear
  - The other gear is connected to the drive train
    - Turns the wheel
    - Will refer to it as the "driven" gear
- Example in illustration
  - Assume
    - Smaller gear is the drive gear
    - Larger gear is the driven gear
    - Driven gear is twice as large as drive gear
      - Drive gear has 12 teeth
      - Driven gear has 24 teeth
  - Operation
    - Figure 1--Drive gear is meshed with driven gear
    - Figure 2
      - Drive gear has turned one-half revolution (6 out of 12 teeth)
      - Driven gear has turned one-quarter revolution (6 out of 24 teeth)
    - Figure 3
      - Drive gear has turned one complete revolution (12 teeth)
      - Driven gear has turned one-half revolution (12 teeth)
    - Figure 4
      - Drive gear has rotated 2 revolutions (24 teeth)
      - Driven gear has rotated 1 revolution (24 teeth)
  - Driven gear turns at one-half the rate (rpm) as drive gear
    - Turns one-half as fast
    - Has twice as much torque

Operation of Transmission

- Transmission connects drive gear to a series of different driven gears
- Transmission allows driver to
  - Change the size of the driven gears
  - Change the speed and torque of the drive shaft
- Provides high torque in order to overcome resistance due to
  - Inertia, when building up speed
  - Gravity, when climbing hills
- Provides high speed when there is little resistance
  - To maintain speed once inertia has been overcome
  - When operating on a level surface

Gear Ratio

- Refers to the relative speed of two gears
  - First number refers to the drive gear
  - Second number refers to the driven gear
- EXAMPLE: Gear ratio of "8 to 1"
  - Drive gear is turning at 8 times the speed of the driven gear
  - Means that the speed of the engine is 8 times that of the drive shaft
  - Torque of the drive shaft is 8 times that of the engine

- (Ask students the ratio of the gears in the visual)
- Driven gear is turning at twice the speed of the drive gear
- Ratio is 2 to 1

Under-Over-Direct Drive

- Underdrive
    - When ratio is greater than 1 to 1
    - Speed of engine is greater than speed of drive shaft
    - Transmission is in underdrive
    - All lower gears are underdrive
- Direct
    - When gear ratio is 1 to 1, vehicle is in direct drive
    - Engine speed equals drive shaft speed
    - It is as if engine crankshaft were directly attached to the drive shaft
    - The highest gear on most transmissions provides direct drive
- Overdrive
    - Any gear ratio less than 1 to 1 is overdrive
    - Speed of drive train exceeds engine speed
    - Provides a lot of speed with very little torque
    - In some tractor transmissions, highest gear is over drive
        - Can increases miles per gallon
        - Can only be used where power requirements are low (level road, light load)
- Designation of transmission
    - Transmissions are frequently described in terms of the number of gears and the gear ratio of the highest gear
    - EXAMPLE: "Ten speed direct" indicates a transmission with ten forward gears, the highest gear being a 1 to 1 gear ratio

Gear Number

- Gears are referred to by number, e.g., 1st gear, 7th gear
- The number refers to relative size of the driven gear
    - The lower the number of the gear, the
        - Larger the physical size of the gear
        - More torque transmitted
        - Less speed transmitted
        - Larger the gear ratio
    - The higher the number of the gear, the
        - Smaller the physical size of gear
        - More speed transmitted
        - Less torque transmitted
        - Smaller the gear ratio
    - Torque is needed to
        - Put a heavily loaded vehicle in motion
        - Climb a steep grade
        - Descend a steep grade under control
    - Speed is needed to
        - Operate at highway speeds
        - Drive cost efficiently

Repeat Visual 8.1 (The Drive Train)

Types of Transmissions

There are three basic types of transmissions: manual, semi-automatic and fully automatic

Manual

- There are three basic ways in which manual transmission components can be arranged
- Multi-speed transmissions
  - Number of forward speeds range from 6 to 20
  - All gears are contained in one housing
  - Driver has control over shifting gears
  - In most cases, shifting is accomplished with
    - One gearshift lever
    - A range selector switch (mounted on lever)
- Combination main and auxiliary transmission
  - Auxiliary transmissions are added to main transmissions to multiply number of shifting speeds
  - EXAMPLE: Main transmission's 5 forward speeds x auxillaries 4 forward speeds = 20 forward speeds available to driver
- Auxiliary transmission mounted just behind main transmission between it and drive shaft
- Shifting this type of transmission requires two independently operated controls
- Some tractors will have
  - Two separate gearshift levers
  - One for each gear box
- Levers are moved in a certain order and progression to shift vehicle
- Other tractors will have
  - One gearshift lever (main box)
  - An auxiliary transmission control device (splitter switch)
- Different settings of auxiliary transmission switch and main transmission gearshift lever gives driver access to as many as 24 forward speeds
- In some cases, auxiliary transmission is power operated using an electrically-operated air assist
- In this case, when switch is moved
  - An electrical connect closes
  - Compressed air is activated, moving gear in auxiliary transmission
- Combination main transmission and variable speed rear axle
  - Two and three speed rear axles work in combination with main transmission
  - EXAMPLE: Main transmissions 5 forward speeds x rear axle's 3 speeds = 15 forward speeds
  - A control knob is mounted on gearshift lever to operate rear axle gears
  - Variable speed rear axles are power shifted, most use an electrically operated air assist

Semiautomatic

- Transmission is shifted manually, in most cases without a clutch
- Some require use of a clutch at 3 mph and below
- All controls are contained in a gear selection box
  - Control box is usually located on driver console
  - Gears are shifted by moving lever to desired number
- Electronic and air powered controls handle most of the work of shifting
- Driver still has responsibility of matching engine speed with road speed when upshifting or downshifting

Automatic

- Transmission is shifted automatically
- Driver controls consist of a range selection panel (similar in some ways to an automobile's)
- The number and type of controls on range selector will vary with different transmissions
- Range selector
  - Is located on driver console
  - Determines by its position which gear range vehicle will operate
  - Each transmission provides a range of gears for its designed application
  - Some automatic transmissions contain
    - Torque converters
      - Multiplies engine torque
        - During starts
        - At slower vehicle speeds
      - Acts as a hydraulic cushion between engine and transmission gears
    - Torque converter (lock-up) clutch
      - Lock-up clutch automatically engages after vehicle is moving and torque demand is low
      - Provides direct drive from engine to transmission (bypasses torque converter)
      - Automatically releases at lower vehicle speeds
      - When lock-up clutch is not engaged, drive from engine is transmitted hydraulically through torque converter to transmission
- Advantages of automatic transmission

Reduced Skill

- Driver does not need experience and skill necessary to select the right moment to upshift or downshift that is required in a manual or semi-automatic transmission
- Driver cannot make an error

Reduced Fatigue

- Correct gear selected automatically

Full Power

- All shifts made at full engine power
- Reduced trip time

Disadvantages
  - Increased weight
  - Increased cost
  - (Fuel penalty is a popular myth--automatics are as fuel efficient as manuals)

Repeat Visual 8.1 (The Drive Train)

Drive (propeller) Shaft: Functions and Components

Function

- Connects the transmission output shaft to the differential at the rear axle
- Connects twin screw tandem axles (interaxle driveshaft)
- Must be capable of
  - Transmitting maximum low-gear torque developed by engine and transmission
  - Rotating at maximum speed required for vehicle operation
  - Operating through constantly changing relative angles between
    - Transmission
    - Drive shaft itself
    - Rear axle
  - Changing length as wheels move up and down, while transmitting torque

Location

- Located between transmission and rear tractor axle(s)
- Between rear tandem axles (twin screw)

Drive Shaft Components

Basic Drive Shaft
- Hollow high-strength steel tube(s)
- Provides
  - Maximum torque carrying capacities at minimum practical weight

Visual 8.9 Types of Drive Shafts

Types
- Single--one tube
- Multiple--two or more connected tubes

Visual 8.10 Slip Joint

Slip Yoke (Joint)
- Consists of
  - External splines on then end of one shaft
  - Matching internal splines on the mating hollow shaft
- Located at
  - Single drive shaft--end of shaft
  - Multiple drive shafts--forward end of rear shaft

- Splines allow shafts to
  - Rotate together
  - Slip back and forth allowing drive shaft to increase or decrease in length
  - Ease strain on axle going over rough roads
- Center bearing (multiple-drive shafts)
  - Used to support center portion of drive shaft when two or more shafts are used
  - The bearing is
    - Of ball-type construction
    - Mounted in a rubber cushion
    - Attached to a frame crossmember

Drive Shaft Vibration

- The drive shaft being comparatively long and made of steel will vibrate even when shaft is balanced
- When shaft is allowed to vibrate excessively over a prolonged period of time, it will eventually
  - Reach a critical speed
  - Break in two
  - Pull loose from mounting brackets
- Most manufacturers set the crtical speed far beyond maximum engine governed speed
- However, when a vehicle with a very long drive shaft or very slow rear axle ratio is allowed to overspeed descending a grade
  - Drive shaft can reach critical speed and break
    - When this happens, extensive damage can occur
      - Air brake lines may be torn out
      - No air to supply brakes
      - Driver will not be able to stop vehicle (if no spring loaded brakes)

Repeat Visual 8.1 (The Drive Train)

Universal Joint

Function

- Connects drive shaft to transmission and rear axle differential
- Allows drive shaft to transmit power from transmission to differential at constantly changing angles
- Needed to compensate for up and down motion of rear axle relative to position of transmission

See Visual 8.1 (The Drive Train)

Location

- Single-drive shaft--both ends of drive shaft
- Multiple shafts
  - At connecting points to transmission and rear axle differential
  - Center point of shafts, connecting them together
- Twin screw tandem axles--at connecting points between axles

Visual 8.11 Universal Joint Components

Universal Joint Components

- Most universal joints are double-hinged, consisting of:
  - Driving yoke
    - Y-shaped yoke connected to transmission output shaft
  - Spider
    - Cross-shaped member connecting driving yoke to driven yoke
  - Driven yoke
    - Connected to drive shaft

Drive Shaft Angle and Length

Single shaft (two universal joints)

- Angularity of front joint should equal that of rear joint
- As rear axle differential and wheels move up and down
  - Angle between transmission and differential changes
  - Length of drive shaft changes
    - Rear axle moves down
      - Angle increases
      - Length decreases
    - Rear axle moves up
      - Angle decreases
      - Length increases

Multiple Shaft (three or more universal joints)

- There are many acceptable combinations of angles for multiple drive shafts with center bearings
- Drive shaft will get shorter (as in single shaft) as the angle increases
- This happens because the rear axle and differential move in a shorter arc than the drive shaft

Visual 8.12 Rear Axle Differential

Differentials and Driven Axles

Function

- Rear axle
  - Supports vehicle and cargo weight
  - Supplies power to wheels through final drive gears
  - Final drive gears
    - Pinion
      - Bevel gear called a pinion, mounted on the end of the drive shaft
    - Ring
      - Mounted on the rear axle and meshes with pinion gear
  - Pinion gear is much smaller than ring gear, resulting in:
    - Reduced speed of drive shaft
    - Increased torque
  - The function of final drive gears is to take torque provided by drive shaft and
  - Increase it (reduce speed)

- Turn it at right angles so it can twist wheels and move vehicle
  - EXAMPLE: Engine has a maximum governed speed of 2200 rpm
    - Crankshaft and flywheel will rotate up to 2200 times per minute
    - If transmission is in high gear (1 to 1 ratio) drive shaft will be turning at 2200 rpm
    - If rear axles did not reduce drive shaft speed, axle and wheels would also be turning at 2200 rpm
    - This would mean truck would be moving over 240 mph
    - In most cases, rear axle final drive gears reduce drive shaft speed by almost 1/4 or more

Differential

- Transfers driving power to wheels by means of independent drive axle shafts (one shaft per wheel)
  - Allows wheels to turn at different speeds when
    - Going around corners
    - Inside wheels
      - Travels shorter distance
      - Must turn slower
    - Outside wheels
      - Travels longer distance
      - Must turn faster
  - Transmits equal torque to wheels, even when one is going faster than the other
  - Differential consits of:
    - Differential case
    - Differential bevel or side gears
    - Differential pinion gears

Repeat Visual 8.1 (The Drive Train)

Location

- Rear Axle
  - Connected by universal joint to the end of drive shaft
- Differential
  - Located in the center of rear axle(s) in a sealed-axle housing

Types of powered rear axles

- There are three basic types of rear axle configurations
  - Single Axle
  - Tandem Axle
  - Tri-Axles

Visual 8.13 Single Rear Axle

- Single Axle
  - Only one rear tractor axle
  - Must be powered
- Tandem Axles
  - Consists of two rear tractor axles
  - Both may be powered or one may be powered; one dead

There are three types:

Twin Screw
Pusher
Tag

Visual 8.14 Twin Screw Tandem

Twin screw--both axles are powered

Visual 8.15 Pusher Tandem

Pusher--rear tandem is powered; front tandem is dead

Visual 8.16 Tag Tandem

Tag--front tandem is powered; rear tandem is dead

Visual 8.17 Powered Tri-Axles

Tri-Axles
- Consists of three rear tractor axles
- May all be powered

These powered axles may be designed like one or more of the following:

Full floating rear axle--
- Designed to provide support of payload and vehicle weight by axle housing
- Wheels are driven by splined shafts which "float" within axle housing
- Shafts carry no load--transmits only the torque

Semi-floating rear axle--
- Designed to provide support of payload and vehicle weight by axle shaft through wheel bearing to axle housing

Single reduction rear axles--
- Final drive ratio is obtained by use of single ring gear and pinion set
- Drive shaft speed is reduced and torque is increased only once before being transferred to wheels
- This type is best for most applications

Double reduction rear axles--
- Final drive ratio is obtained by use of single ring gear and pinion set in combination with a secondary gear set
- Drive shaft speed is reduced and torque is increased twice before reaching rear wheels

- This type is only used when
  - High torque is required
  - High speeds are not encountered
  - EXAMPLE: Off-road vehicles

- Two-speed drive axle--
  - Provides two-speed torque power
  - Final drive ratios are obtained by use of single-ring gear and pinion set in combination with secondary gear set (as in double reduction axles)
  - Has the facility to shift from using only the single ring gear and pinion set (as in a single reduction axle) to using both sets of reduction gears (double reduction)
  - Doubles the gear range of the drive train

- Three speed drive axle
  - Provides three gear ranges
  - Used with twin screw tandem
  - Final drive ratios are obtained as follows:
    - Axles are operated in either low, intermediate or high range
      - Low range--both two-speed axles are shifted to low range
      - Intermediate range
        - Front tandem shifted to high
        - Rear tandem shifted to low
      - High range--both axles are shifted to high range
- Triples the gear range of the drive train

Repeat Visual 8.1 (The Drive Train)

- Interaxle Differential
  - Also called Power Divider
  - Used with tandem twin screw axles
  - Interaxle differential has two control positions, lock and unlock
  - Unlock position
    - Permits differential action between axles
    - Used for all normal driving when traction is good
    - The interaxle differential in the unlock position
      - Divides torque received by drive shaft, between both drive axles
      - Compensates for differences in axle speed due to tire mismatch or wear
    - In unlock position
      - If one axle or wheel of tandem is on ice and loses traction, second axle cannot develop traction because differential demands each axle receive the same torque
    - In locked position
      - Prevents interaxle differential from operating
      - Used when icy, poor traction areas are present

- The interaxle differential in the unlock position
  - Divides torque received by drive shaft, between both drive axles
  - Compensates for differences in axle speed due to tire mismatch or wear
- In unlock position
  - If one axle or wheel of tandem is on ice and loses traction, second axle cannot develop traction because differential demands each axle receive the same torque
- In locked position
  - Prevents interaxle differential from operating
  - Used when icy, poor traction areas are present
  - The interaxle differential in the locked position
    - Provides straight through positive power to both axles
    - Allows either axle to drive up to its maximum tractive ability without regard to the other

Interaxle differential operation--
- Selector switch in cab is marked Lock and Unlock
- Switch should be moved to lock position when approaching or anticipating icy or poor traction areas
  - Let up on accelerator
  - Move switch to lock position
- When adverse conditions have passed, switch back to unlock position
- Do not wait until you have lost traction and your wheels are spinning to lock inter-axle differential
- This could
  - Tear out inter-axle differential
  - Break inter-axle drive shaft
  - Possibly destroy entire drive train

Visual 8.18 Front Driving Axles

Powered front (steering) axles--
- Provides pull power (front axle) as well as push power (rear axle(s))
- Distributes pulling power to two additional wheels
- Provides extra traction
- Useful where tires do not have a firm grip on the road surface
  - Slippery pavement
    - Particularly in mountainous areas
    - Extra traction is needed
  - Off-highway operation
    - Mud
    - Sand

A transfer case redirects engine power from transmission to front axle
Level arrangement in cab allows driver to
- Send power to front axle when extra traction is needed
- Take power away when not needed

Locating and Recognizing Problems

Inspection

During inspection, driver should check for

- Leaks of transmission fluid, rear axle lube, or flinging of grease by universal joint
- Clutch pedal freeplay

Servicing

Make sure transmissionand rear axle are kept filled with proper grade and type of lube oil.

Operation

While vehicle is in operation, driver should.

- Not try to shift transmission gears without use of the clutch
- Monitor instrument panel gauges for transmission and axle lube temperatures.
- See that they are in the proper range (approximately 150 to 160°)
- Become fully familiar with operator's manual for vehicle
- Learn how to use the following properly
    - Shift patterns.
    - Progressive shifting.
    - Clutch brake (if vehicle so equipped).
    - Coordination of auxiliary transmission and/or multi-speed rear end.
    - Inter-axle differential controls (if vehicle so equipped).

Post-trip Inspection

Report any of following:

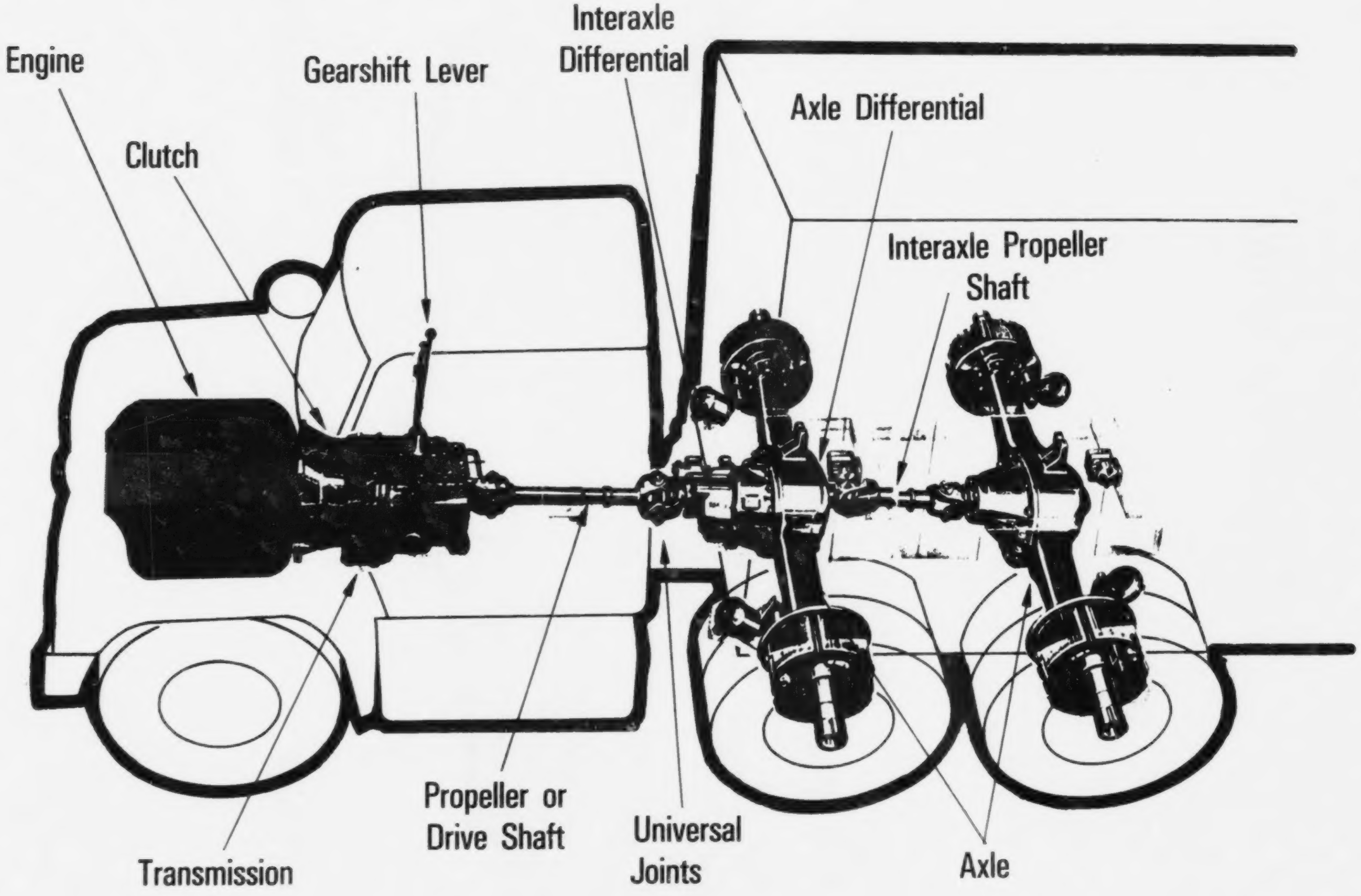
- Hard shifting
- Grinding when shifting
- Noisy shifting
- Excessive clutch play

Recap

- Drivers need to know type of drive train used by their vehicle and operating characteristics.
- Drivers unfamiliar with a particular vehicle cannot assume that it is the same as vehicle last operated.
- Not being familiar with characteristics of drive train can result in improper shifting, causing
    - Lugging or overrevving of engine.
    - Waste of fuel.
    - Damage to gears, clutch, engine.
- When operating a vehicle with an unfamiliar drive train, drivers should:
    - Read operators manual.
    - Obtain expert advice on shift points, shifting techniques, and limitations of drive train.
- It is driver's responsibility as a professional to take care of the drive train to extend the operating life.

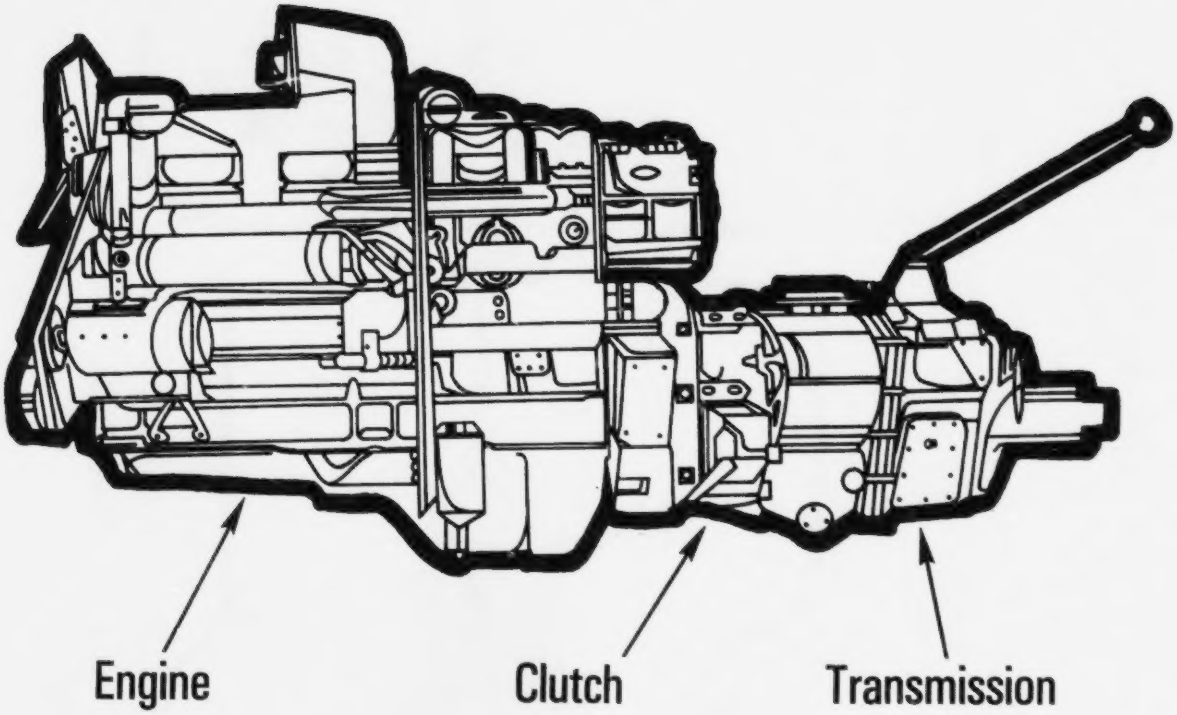
Visual 8.1

The Drive Train


Engine
Clutch
Gearshift Lever
Interaxle Differential
Axle Differential
Interaxle Propeller Shaft
Transmission
Propeller or Drive Shaft
Universal Joints
Axle

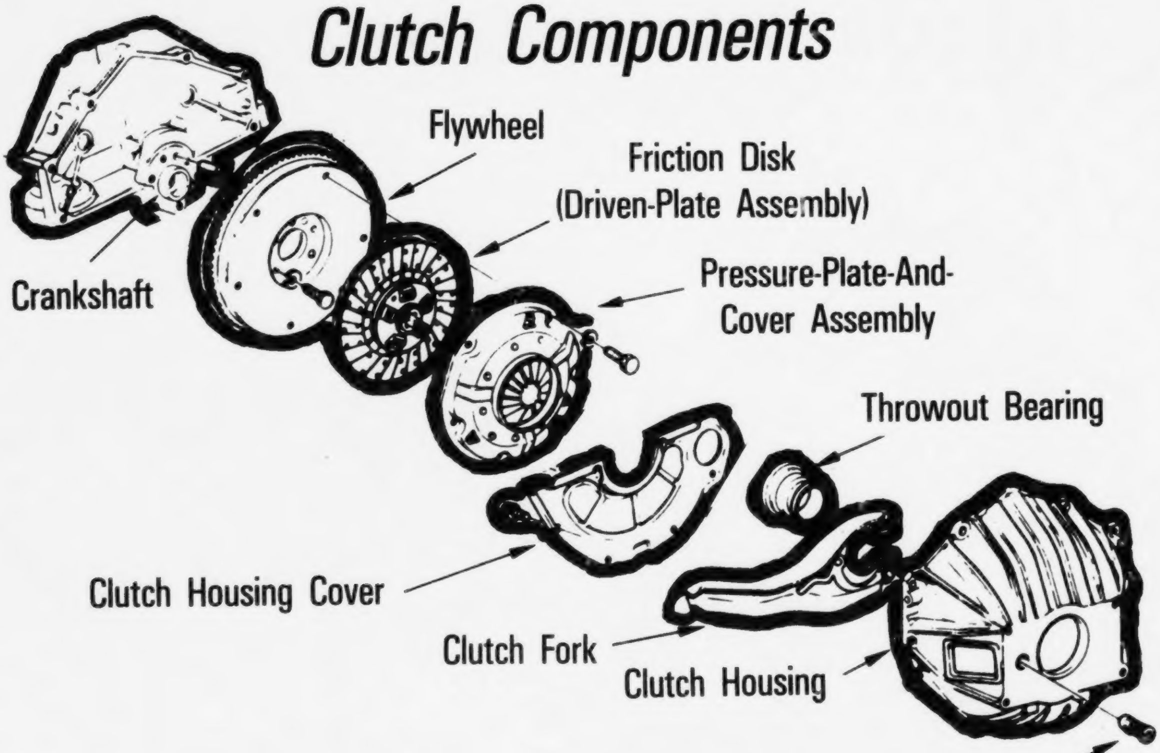
Visual 8.2

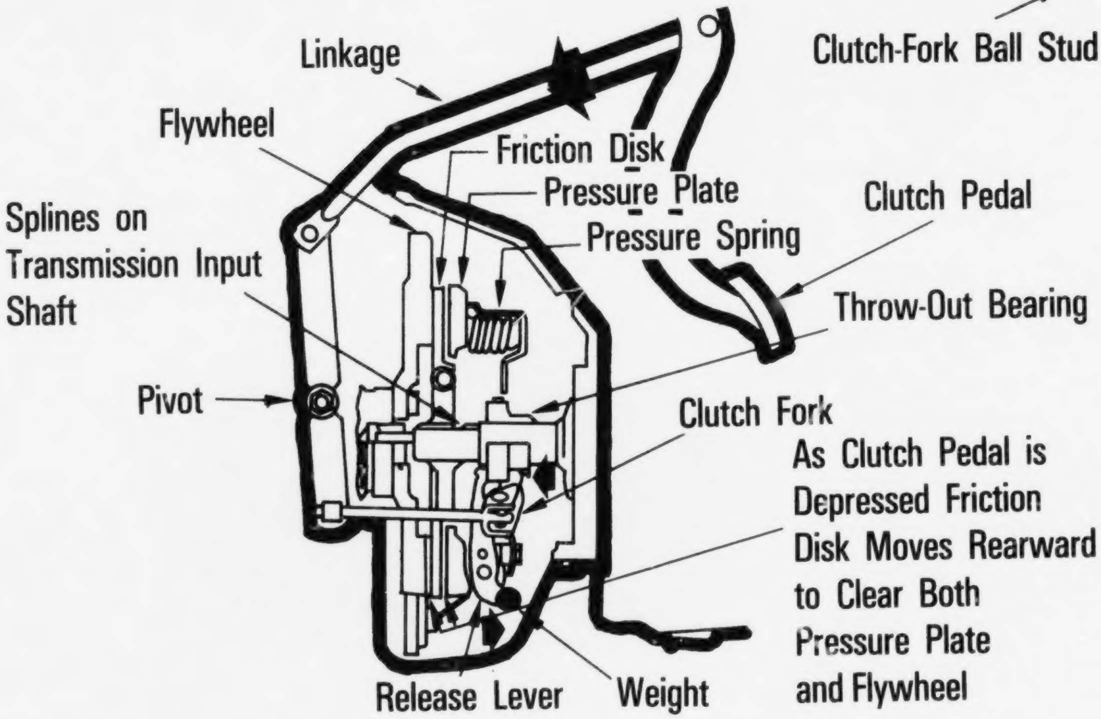
Clutch Location


Engine
Clutch
Transmission

Visual 8.3

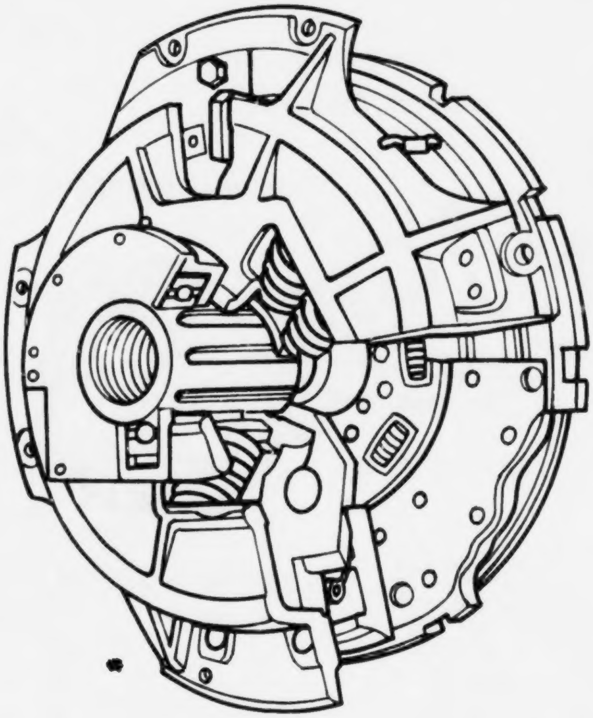
Clutch Components

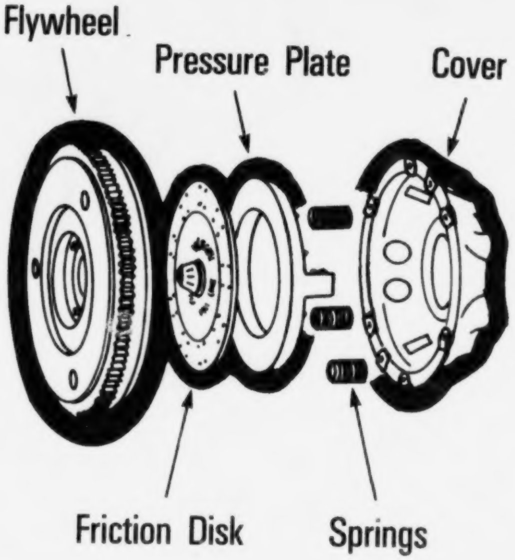

Flywheel
Friction Disk
(Driven-Plate Assembly)
Crankshaft
Pressure-Plate-And-
Cover Assembly
Throwout Bearing
Clutch Housing Cover
Clutch Fork
Clutch Housing
Clutch-Fork Ball Stud


Linkage
Flywheel
Friction Disk
Pressure Plate
Pressure Spring
Clutch Pedal
Splines on
Transmission Input
Shaft
Throw-Out Bearing
Pivot
Clutch Fork
As Clutch Pedal is
Depressed Friction
Disk Moves Rearward
to Clear Both
Pressure Plate
and Flywheel
Release Lever
Weight

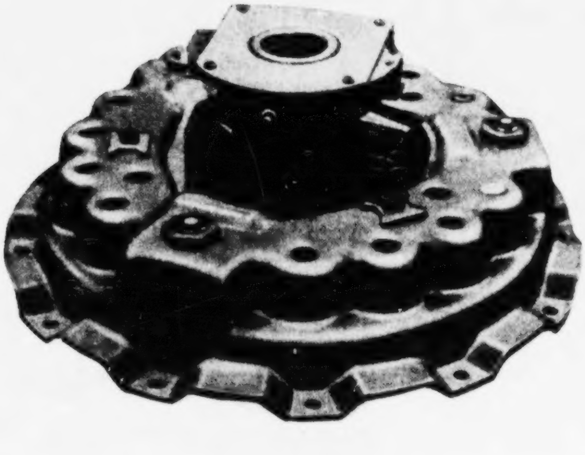
Visual 8.4

Pressure Plate and Cover Assembly

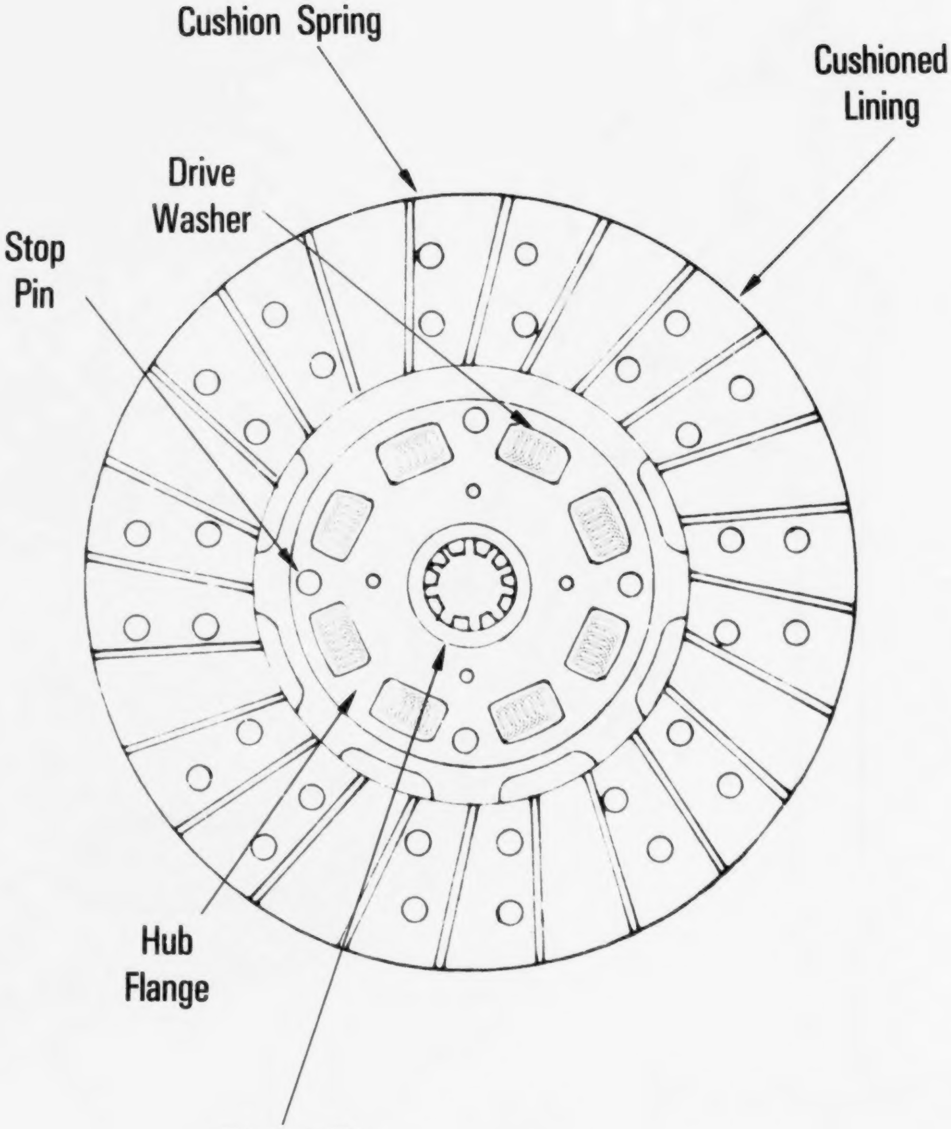




Flywheel
Pressure Plate
Cover
Friction Disk
Springs

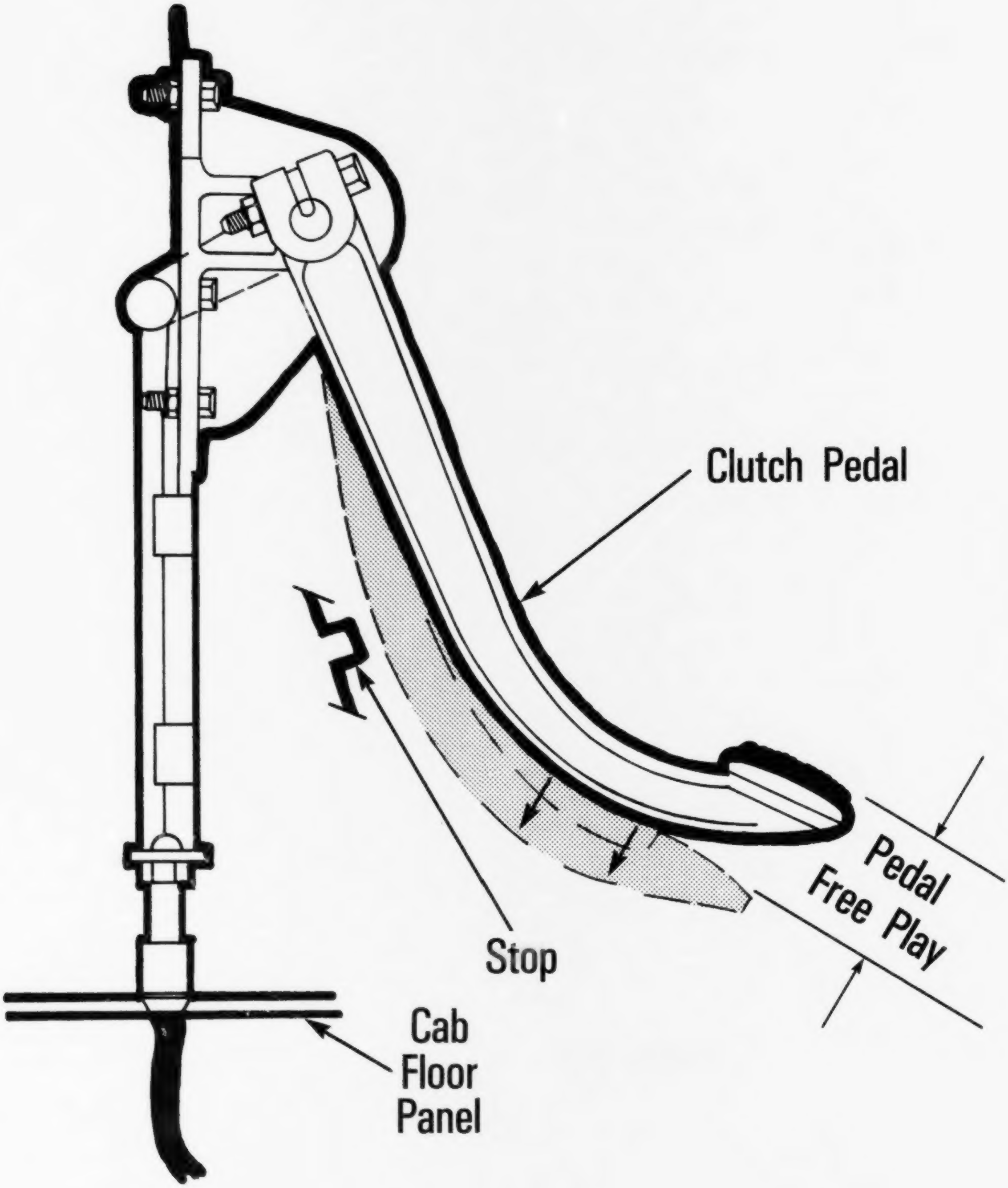


Clutch Disk


Cushion Spring
Cushioned Lining
Drive Washer
Stop Pin
Hub Flange
Friction Ring

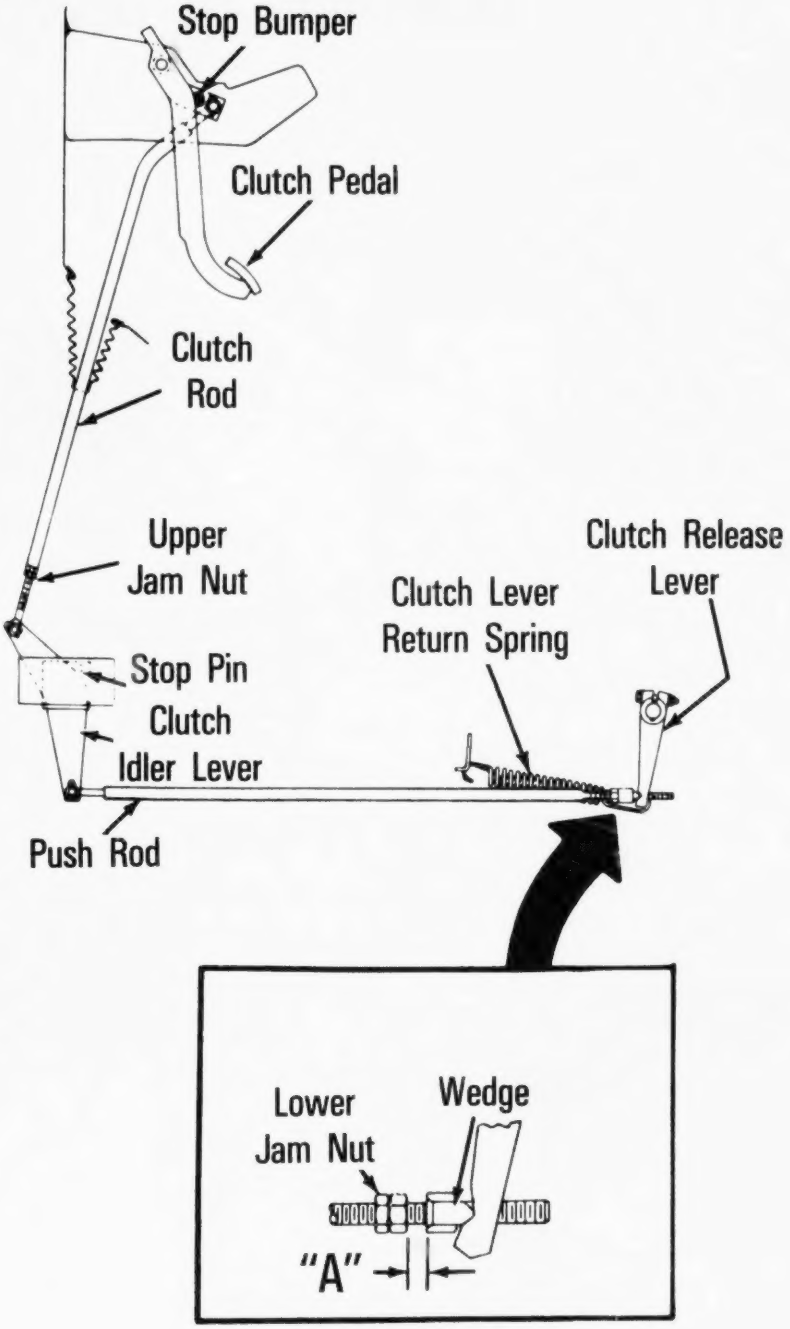
Visual 8.6

Clutch Free Travel


Clutch Pedal
Pedal Free Play
Stop
Cab Floor Panel

Visual 8.7

Clutch Linkage Adjustment


Stop Bumper
Clutch Pedal
Clutch Rod
Upper Jam Nut
Stop Pin
Clutch Idler Lever
Push Rod
Clutch Lever Return Spring
Clutch Release Lever
Lower Jam Nut
Wedge
"A"

Clutch Clearance
At Point "A"

Visual 8.8

Operation of Gears

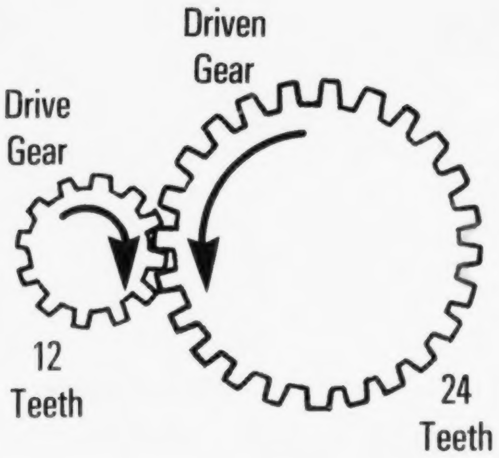

Driven
Gear
Drive
Gear
12
Teeth
24
Teeth

Figure 1

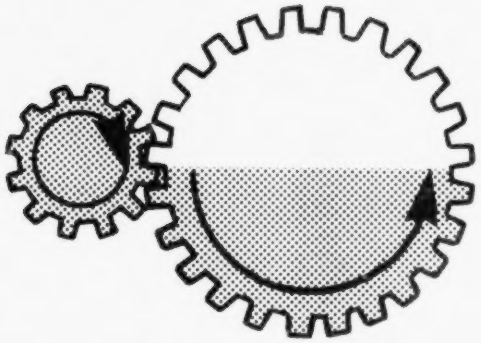


Figure 3

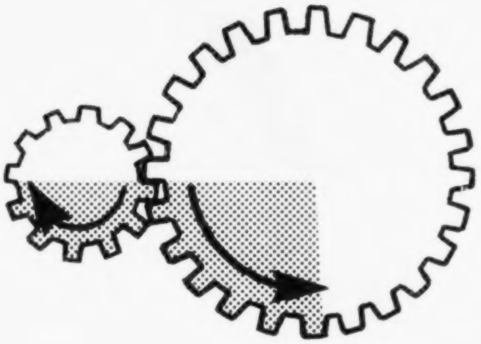


Figure 2

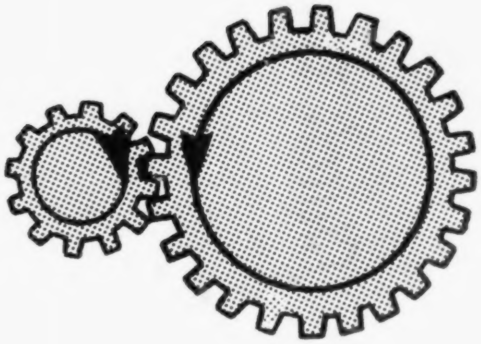
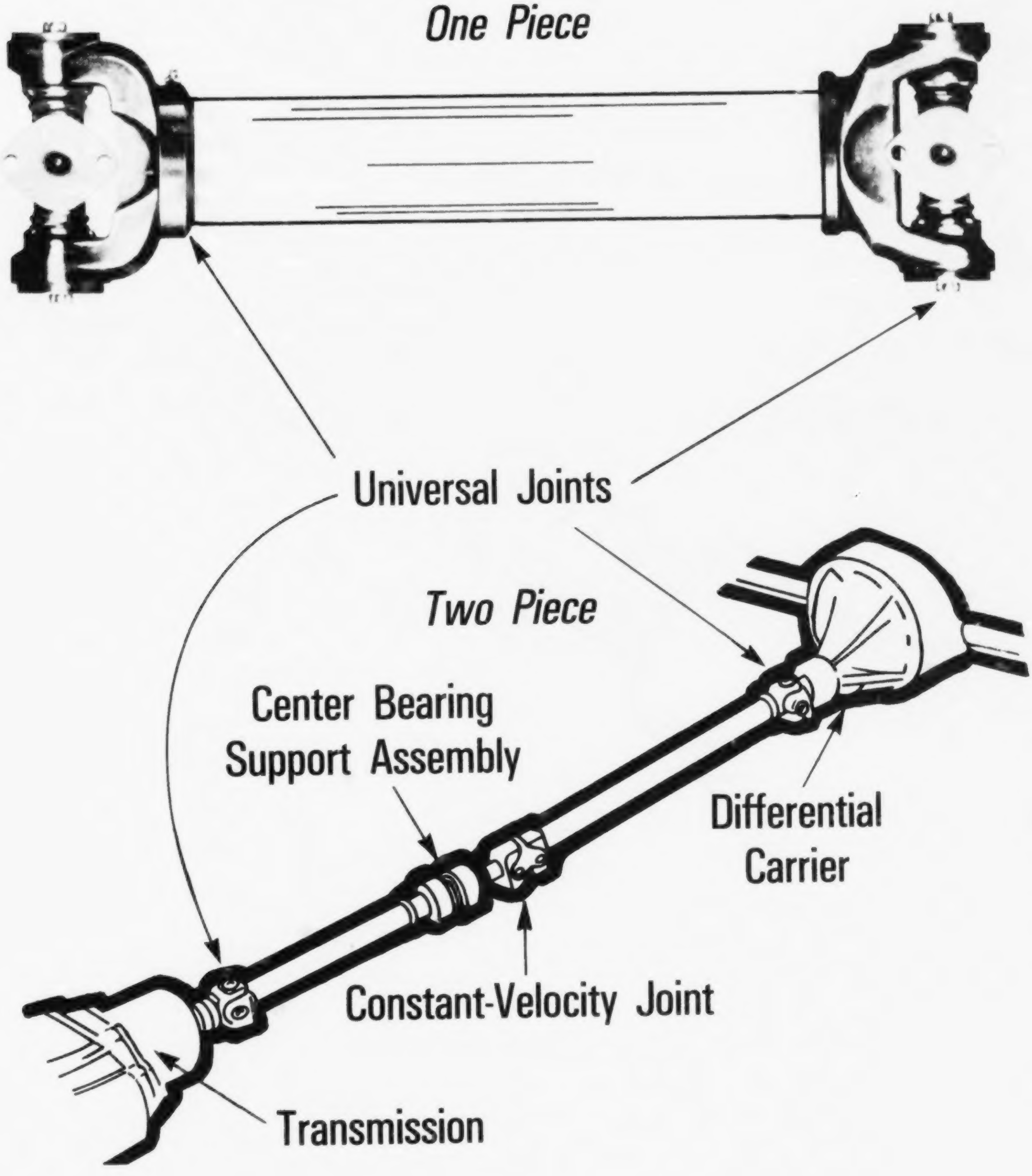


Figure 4

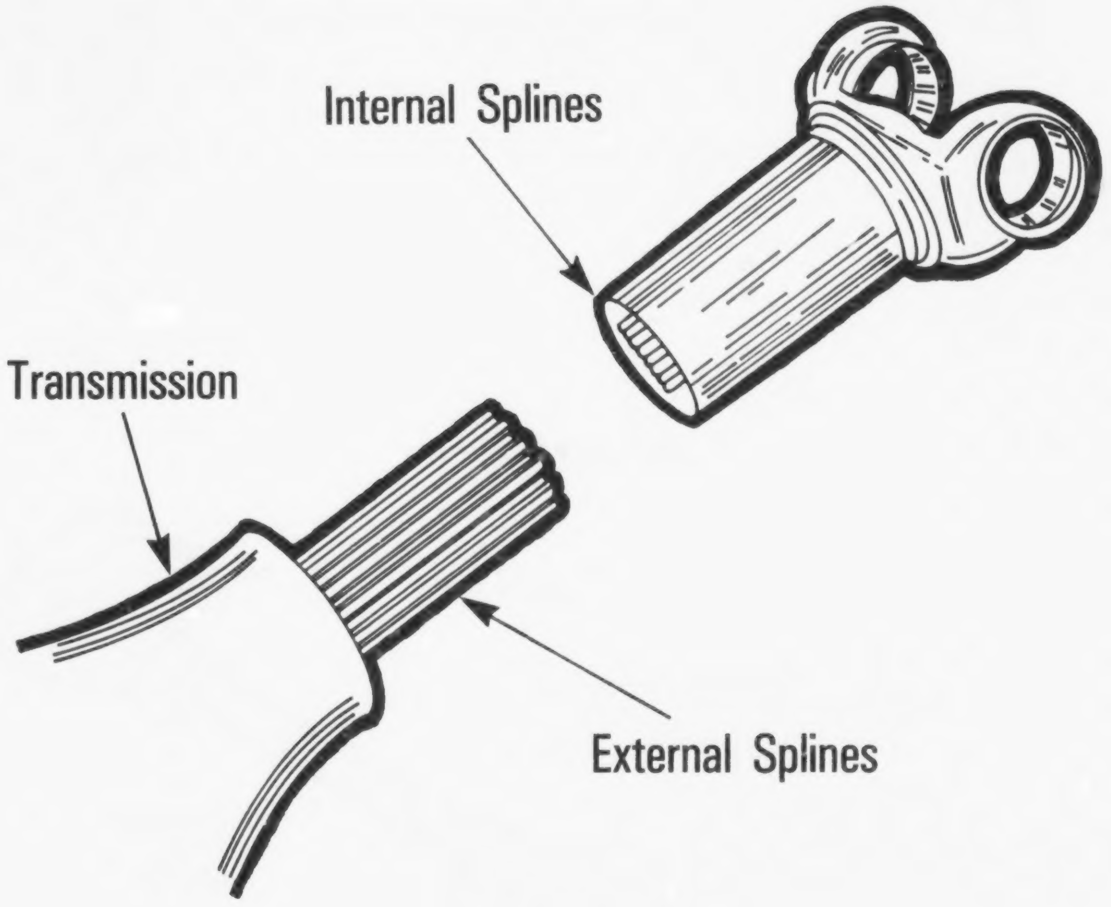
Visual 8.9

Types of Drive Shafts


One Piece
Universal Joints
Two Piece
Center Bearing Support Assembly
Differential Carrier
Constant-Velocity Joint
Transmission

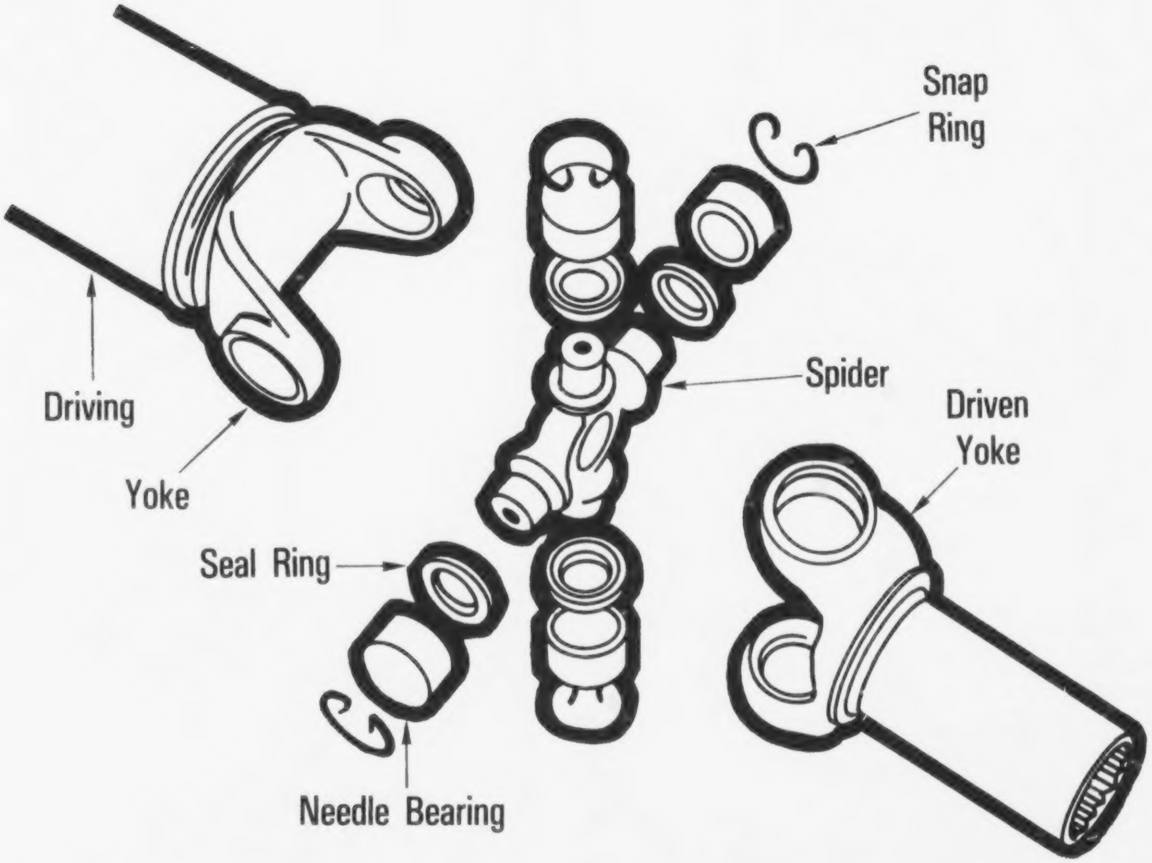
Visual 8.10

Slip Joint

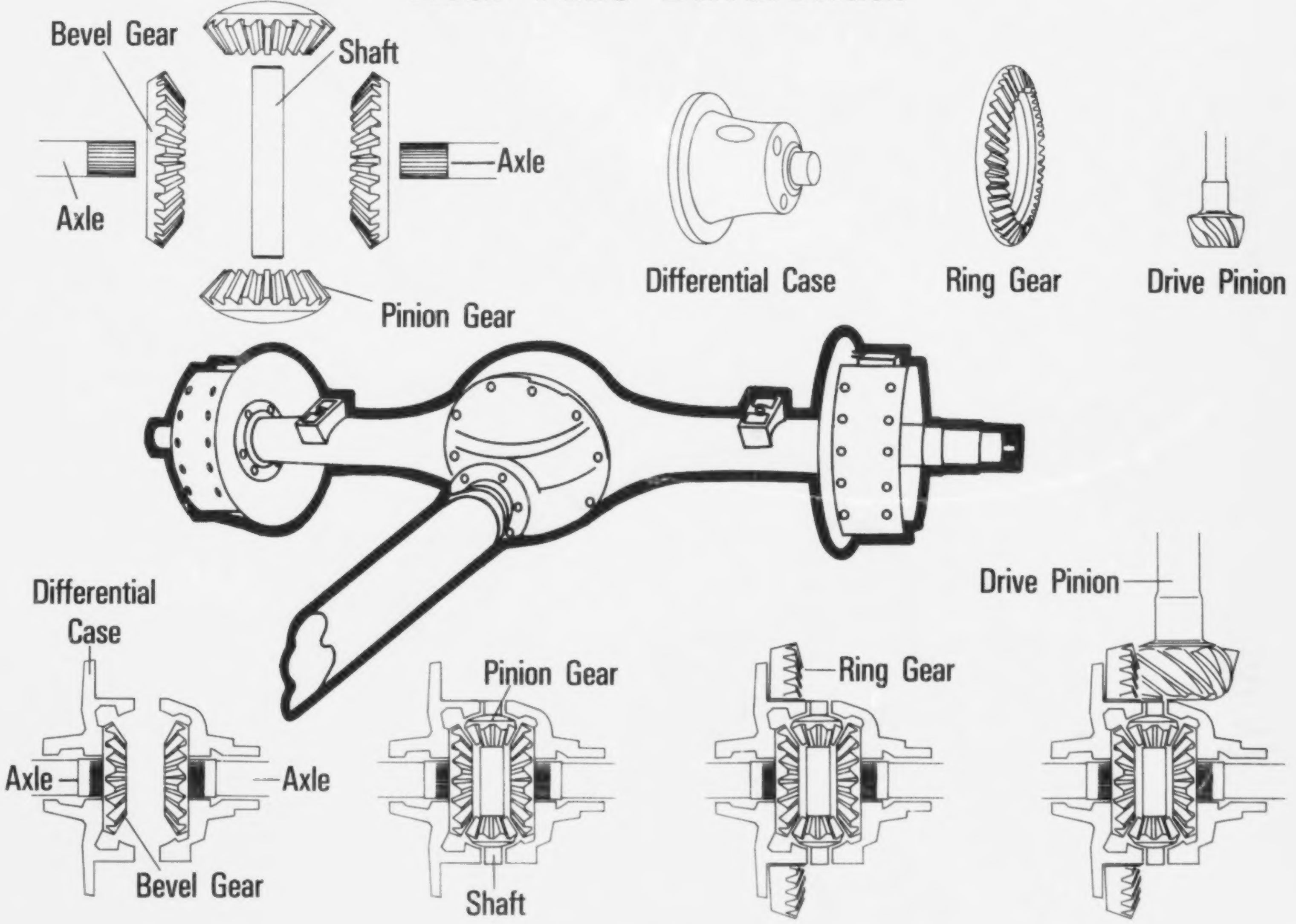

Internal Splines
Transmission
External Splines

Visual 8.11

Universal Joint Components

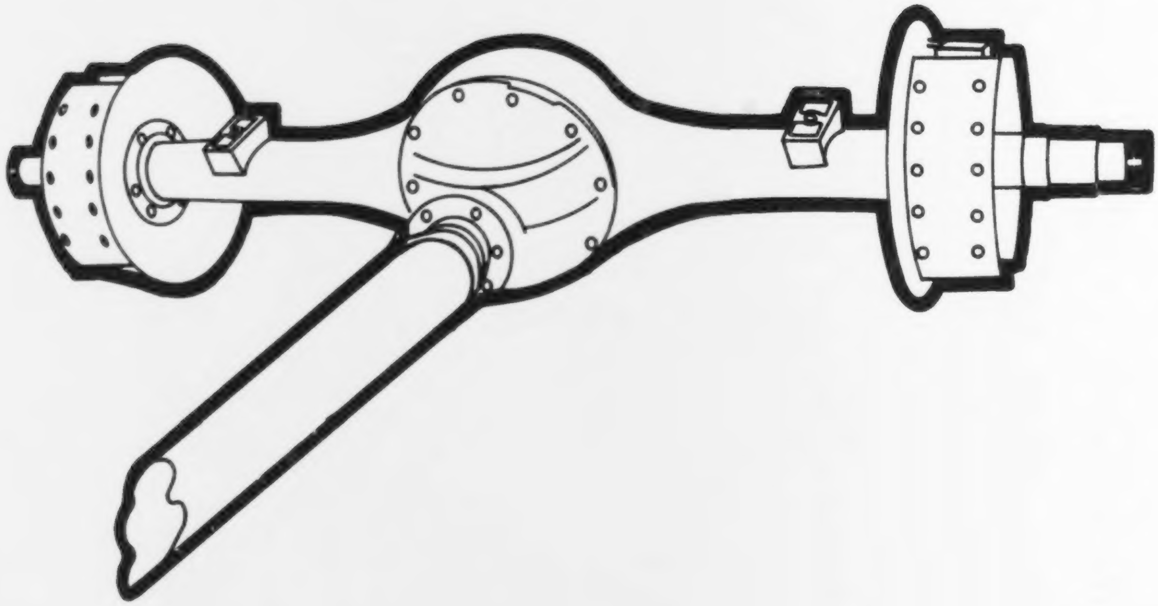

Snap Ring
Spider
Driven Yoke
Driving Yoke
Seal Ring
Needle Bearing

Rear Axle Differential


Bevel Gear
Shaft
Axle
Axle
Pinion Gear
Differential Case
Ring Gear
Drive Pinion
Differential Case
Axle
Axle
Bevel Gear
Pinion Gear
Shaft
Ring Gear
Drive Pinion

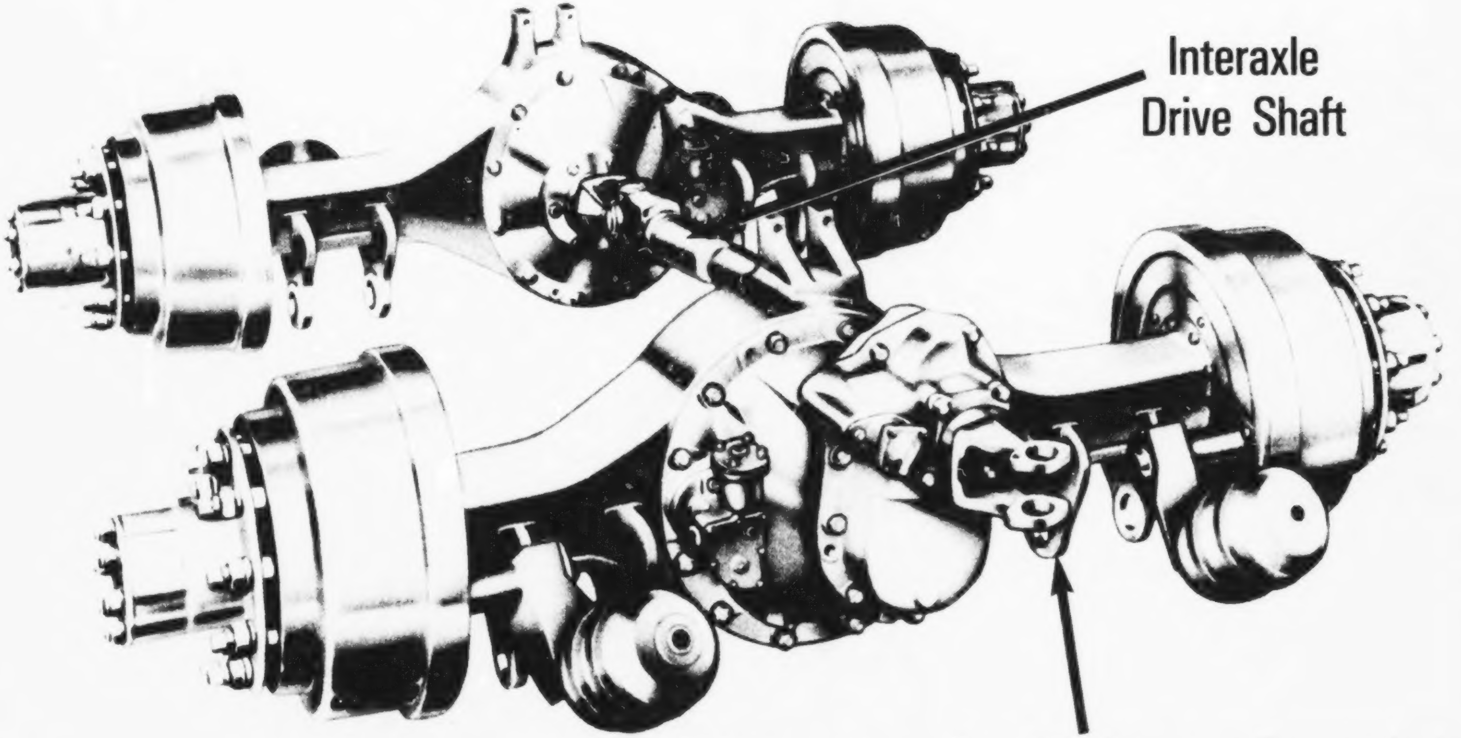
Visual 8.13

Single Rear Axle



"Twin Screw" Type Tandem Axles

Both Axles Powered



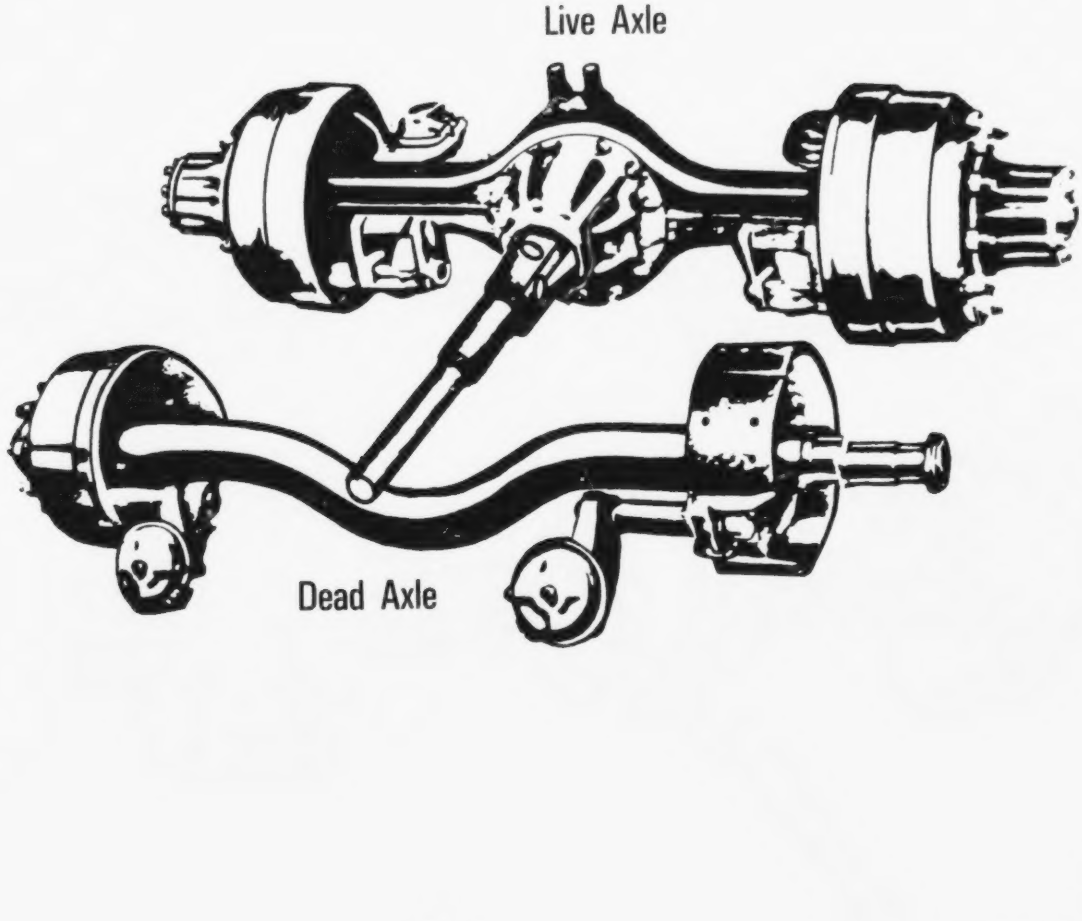
Interaxle
Drive Shaft

Drive or Propeller Shaft From Transmission
Connects to This Universal Joint

Visual 8.15

"Pusher" Type Tandem Rear Axles

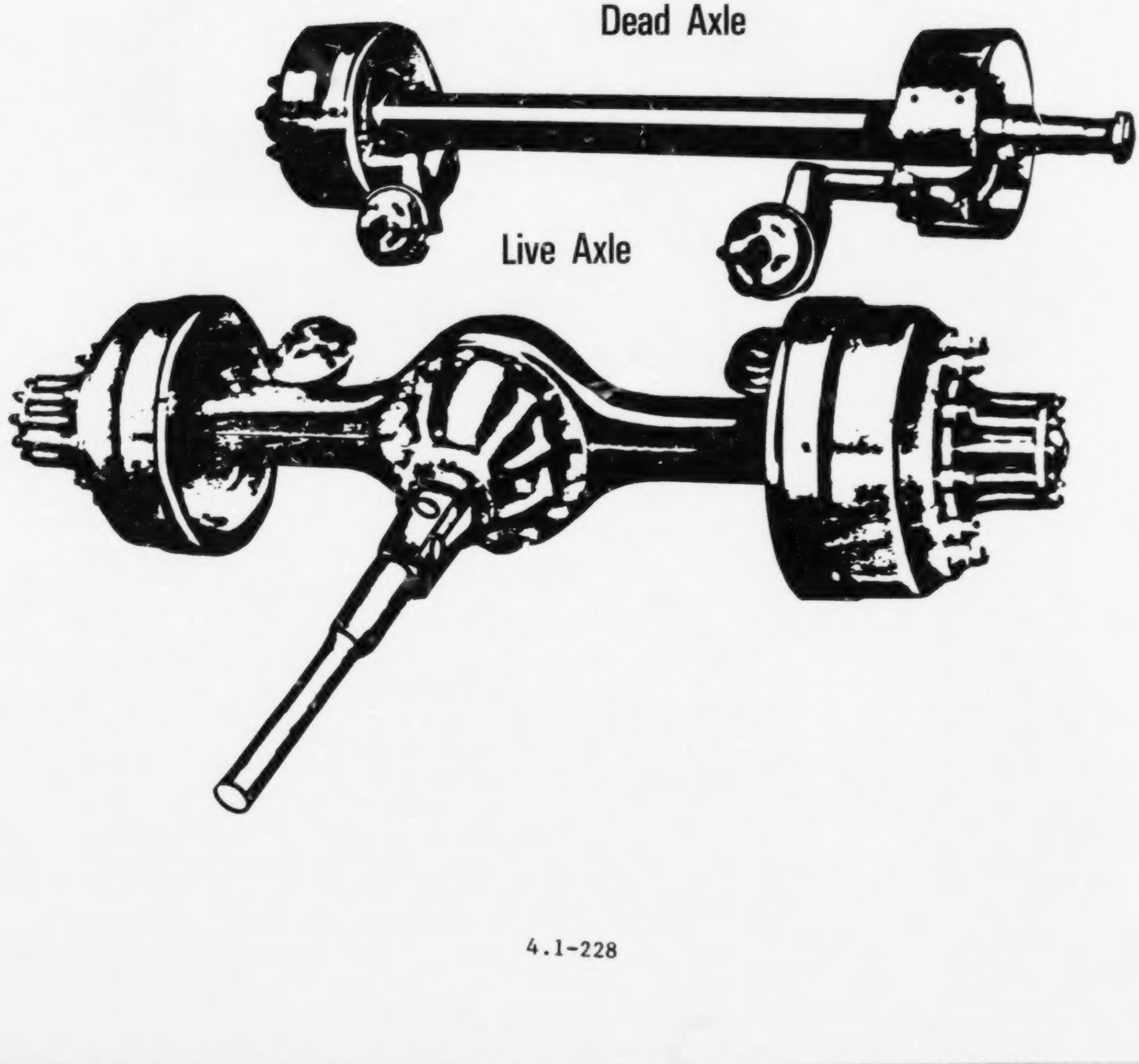
Front Axle Dead,
Rear Is Powered


Live Axle
Dead Axle

Visual 8.16

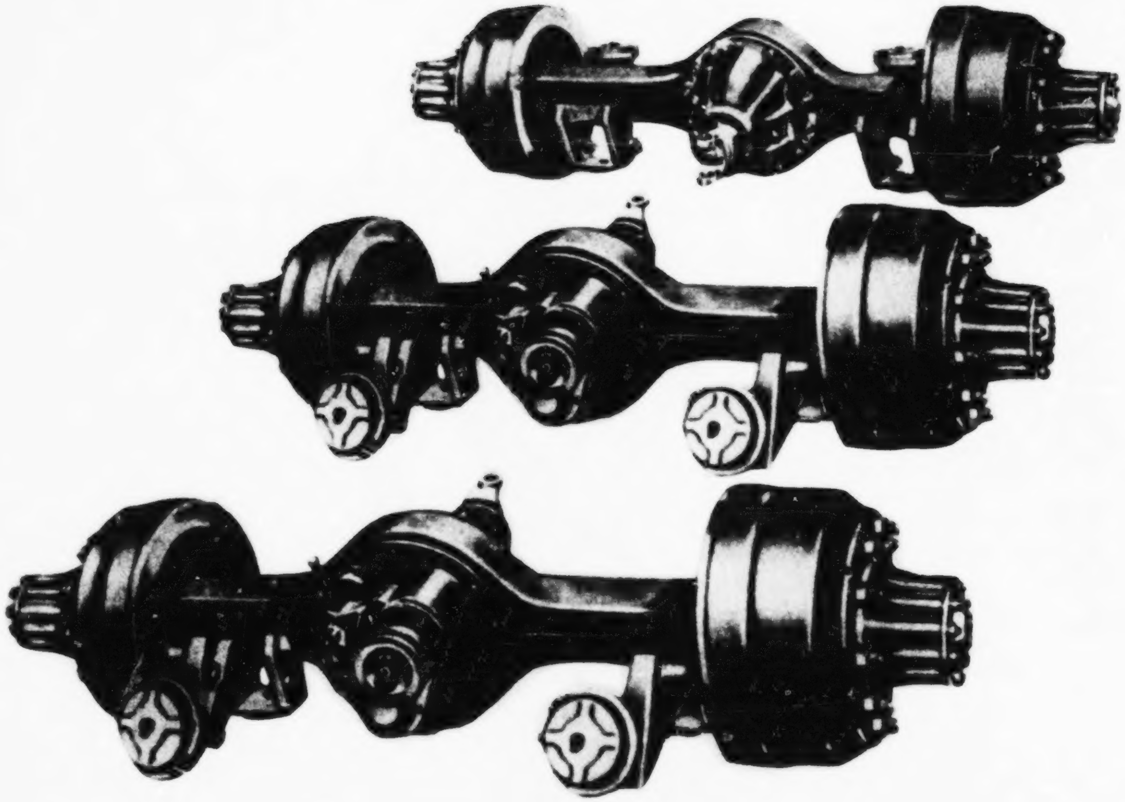
"Tag" Type Tandem Rear Axles

Front Axle Powered,
Rear Axle Dead


Dead Axle
Live Axle

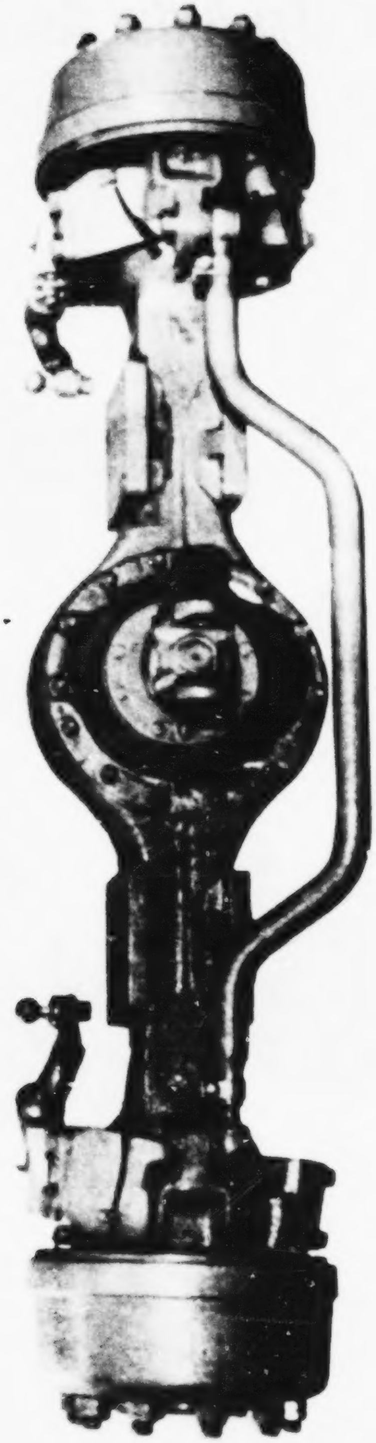
Visual 8.17

Rear Tri-Axle Assembly All Three Powered



Visual 8.18

Front Driving Axles



9. BRAKE SYSTEMS (2 hours 45 minutes)

Introduction

This topic is designed to give students a fundamental working knowledge of the

- Theory of modern heavy-duty vehicle compressed air brake systems
- Major components of the air brake system and how they function
- Methods for inspecting and detecting air brake system problems and/or impending malfunctions
- Proper braking techniques for air braked vehicles
- Theory of various types of auxiliary brakes (speed retarders)
- Major components of the more common types of speed retarders and how they function
- Proper operation and inspection techniques for most common types of retarders
- Brake systems' key role in safety and cost per vehicle mile of operation as well as how that role can be favorably or unfavorably impacted by driver's actions

Purpose

Tractor-trailer brakes are used to slow, stop, and secure (park) the vehicle by

- Retarding wheel speed
- Eliminating wheel speed entirely

Brake Theory

Kinetic Energy Versus Heat Dissipation

- Engines convert heat energy into kinetic energy (energy of motion)
- In stopping a vehicle
  - Kinetic energy must be transformed back into heat energy
  - Heat energy must be dissipated into atmosphere
- The action of stopping a vehicle requires
  - Forcing brake shoe linings against surface of brake drums or disks
  - Creating friction which produces heat
- Friction between brake drums or disks and brake linings reduces kinetic energy of the revolving brake drums or disks and wheels
- The generated heat must be
  - Absorbed by the drum or disk
  - Given off into the atmosphere
- Amount of heat drums or disks can absorb depends upon thickness of metal

Forces Involved in Braking

- A 100-horsepower engine can accelerate a vehicle to 60 mph in 60 seconds
- Brakes are required to stop the same vehicle traveling 60 mph in 6 seconds (or 1/10 the acceleration time)
- Brakes must absorb and dissipate heat energy equal to ten times engine power or 1000 h.p.
- If vehicle has 10 brake chambers (standard 18 wheel tractor-trailer) then each brake would be required to
  - Produce 1/10 the stopping power or
  - Absorb heat generated by 100 h.p. of brake effort
- If one or two wheels have poorly adjusted brakes, then:
  - Remaining brakes would have to produce more than their share of the work, resulting in
  - Brakes doing more work than they were constructed to stand
- Amount of work done by the brakes determines amount of heat generated that must be dissipated
- Average tractor-trailer brake is designed to handle approximately 50-60 h.p. of brake effort at each wheel more or less continually
- In emergency situations the amount (50-60 h.p.) could increase considerably
- EXAMPLE: (as described earlier)
  - Brakes stopping vehicle going 60 mph
  - Absorbing and dissipating 100 h.p. of brake effort
  - After brakes have made an emergency stop (such as the above)
  - Brakes need to be rested so they can cool
  - Continued use would result in
    - Build up of more heat than can be dissipated
    - Brake damage and/or possible failure

Effect of Weight and Speed on Brakes

- Stopping power required varies
  - Directly as the weight, and
  - As the square of the speed
- When vehicle weight is doubled, stopping power must be doubled
- EXAMPLE: A 60,000-pound vehicle needs twice the stopping power of a 30,000-pound vehicle traveling at the same speed
  - When vehicle speed is doubled, stopping power must be increased 4 times
- EXAMPLE: A vehicle traveling 40 mph needs four times as much stopping power as it did at 20 mph
  - When vehicle weight and speed are doubled, stopping power must increase 8 times
- EXAMPLE: A 60,000-pound vehicle traveling 40 mph needs 8 times the stopping power of a 30,000-pound vehicle traveling 20 mph

Force Multipliers

- All types of braking systems make use of devices to gain a mechanical advantage
- In order to develop force required to
    - Hold brake linings against brake drum or disk
    - Achieve controlled deceleration
- It is necessary to use
    - A source of power
        - Compressed air
        - Hydraulic fluid
    - A system of levers
        - Slack adjuster and cam
        - Brake shoe
        - Wheel and brake drum
    - A combination of both

Visual 9.1 Levers Used in Braking

Levers Used in Braking

In Visual 9. Figure 1

- Lever A-B is placed over pivot point C (fulcrum)
- Distance from A to C is 4 feet
- Distance from C to B is 1 foot
- This creates a ratio of 4 to 1

Figure 2

- When a downward (applied) force of 100 pounds is applied to point A, then upward (delivered) force at point B will be 4 x 100 lbs = 400 lbs. (the force has been multiplied

Figure 3

- This is how it works in a brake system:
- A simple lever system can be applied to a
    - Slack adjuster and cam
    - Brake shoe
    - Wheel and brake drum
- Force from brake chamber pushes against slack adjuster (applied force)
    - Slack adjuster rotates cam shaft
    - Delivered force will be at point where end of brake shoe rests against cam
- Delivered force at this point now becomes applied force on end of brake shoe
    - Fulcrum is at anchored end of brake shoe
    - Delivered force is at center of brake shoe
- Delivered force at this point now becomes applied force at brake drum surface
    - Fulcrum is at center of wheel
    - Delivered force is at road surface

- The original force from brake chamber
  - Is multiplied through a system of levers
  - Finally becomes a magnified retarding force delivered at road surface
  - Tractor-trailers hauling several thousand pounds of cargo at highway speeds need an additional force multiplier to assist lever system
- There are two basic power sources used today in the trucking industry

Air as a Source of Power (Force Multiplier)

- Air is compressible
  - A given amount of air can be squeezed (e.g., compressed) into a smaller space than it normally occupies
  - The smaller the space it is forced into, the greater the resistance to be squeezed (e.g., pressure) it will have
  - Pressure is used to gain a mechanical advantage
  - Compressed air is a force multiplier
- The force that compressed air exerts is measured in pounds per square inch p.s.i.
- When compressed air is directed through a small pipe into a large brake diaphragm the force or power of air is multiplied

Visual 9.2 Air As a Force Multiplier

EXAMPLE:
- 80 p.s.i. air pressure exerted on a brake diaphragm 10 square inches in area will result in
  - Force being multiplied 10 times
  - 80 p.s.i. x 10 square inches = 800 pounds of force
- This force is then applied to
  - Slack adjuster and cam
  - Brake shoe
  - Wheel and brake drum
- And eventually delivered at road surface to stop vehicle

Hydraulic Fluid as a Source of Power

- Fluids are not compressible
- However, when a quantity of a fluid contained in a large diameter cylinder is forced into a smaller diameter container (e.g., hose, wheel cylinder) a resistance to change or pressure is created
- Pressure is used to gain a mechanical advantage
- Hydraulic fluid is a force multiplier

Visual 9.3 Straight Hydraulic System

A hydraulic system consists of a
- Fluid reservoir
- Master cylinder
- Wheel cylinders
- Connecting tubes of metal or rubber

When brake pedal is depressed

- Force is applied to a pushrod in master cylinder
- Push rod forces a piston in cylinder forward
- Piston applies pressure to hydraulic fluid, forcing it into small diameter brake lines and wheel cylinders
- Fluid in cylinders forces brake shoe linings against drum or disk to stop vehicle

When hydraulic fluid in master cylinder is forced through smaller diameter hoses into a smaller wheel cylinder, the force or power of fluid is multiplied

Pressure in a hydraulic system is transmitted equally to all parts of system

Additional force exerted on foot pedal
- Builds up more pressure in system
- Is transferred to drum or disk and eventually to the road surface

The energy resulting from hydraulic fluid under pressure is converted to mechanical energy to stop vehicle

Straight hydraulic brakes are used on all types of commercial equipment from the lightest to heaviest vehicles

The exception being articulated vehicles (e.g., tractor-trailers)

Reasons why

- Connections between tractor and trailer would be critical because of
  - Possibliity of fluid loss
  - Required high pressures
- Amount of fluid needed to activate wheel cylinders in an 18-wheel tractor-trailer would be impractical to carry and store
- There would be an immediate loss of brakes in the event of failure of system

However, hydraulic activated brakes do have some advantages

- Faster activation -- less lag time
- High brake line pressure permits use of small components
- Less expensive

Although straight hydraulic brake systems are not used in articulated vehicles
They are used in combination with compressed air systems
This type of system is known as Air-over-Hydraulic

Visual 9.4 Air-Over-Hydraulic System

- Air-Over-Hydraulic System
  - This type of system consists of
    - Tractor--hydraulic brakes using air pressure to assist in braking effort
    - Trailer--equipped with air-operated brakes
  - An air-over-hydraulic system
    - Activates tractor brakes hydraulically
    - Depends upon compressed air for its source of power
    - Activates trailer brakes using compressed air only
  - Contains
    - A power cluster or air pak
    - An attached slave cylinder
    - Components from both hydraulic and air brake systems
  - The power cluster or air pak
    - Converts applied air pressure to hydraulic pressure
    - Contains a diaphragm attached to a piston in the slave cylinder
  - When brakes are applied
    - Air pressure applies force against diaphragm
    - Diaphragm moves piston in slave cylinder against hydraulic fluid
    - Pressure is exerted on fluid which in turn forces brake shoes against drum in tractor wheel cylinders
    - At the same time compressed air travels to trailer brakes where air pressure alone supplies force to activate brakes
  - Compressed air and hydraulic fluid work well together as force multipliers
  - However, the most efficient and popular braking system utilized by articulated vehicles on the road today is the air brake system

Components and Functions

Parts of Tractor-Trailer's Air Brake System

- Air brake equipment on tractor-trailers provide a means of controlling brakes through the medium of compressed air
- Air brake equipment consists of a group of devices
  - Some maintain a supply of compressed air
  - Some direct and control flow of compressed air
  - Others transfer energy of compressed air into mechanical force and motion necessary to apply brakes
  - Different types and sizes of devices are used in different types of vehicles to meet operating requirements but they are all fundamentally the same

Components - Purpose and Function

Visual 9.5 Air Brake System Components and Location

- Air Compressor
  - Designed to compress and pump air
  - The most common type operates similar to a reciprocating engine
  - Can be either:

Visual 9.6 Reciprocating In-Line Air Compressor (Two Cylinder)

- Two or four cylinder (most are two)

Visual 9.7 Reciprocating Vee Air Compressor (Four Cylinder)

- In-line or vee construction (in-line most common)
- Belt and pulley or shaft and gear driven
- Water or air cooled
- Self- or engine-lubricated
- Operation
  - Operating principle similar to intake and compression strokes of a four-stroke cycle reciprocating engine
  - Rotation of compressor crankshaft causes pistons to move up and down in the cylinders
  - Intake stroke
    - Inlet valves open permitting air to enter cylinders
    - Discharge valves closed
    - Piston moves down
  - Compression stroke
    - Inlet valves close
    - Piston moves up compressing air
    - Discharge valves open permitting compressed air to flow through discharge line to air reservoirs
  - Compressor is in constant drive with engine
    - When engine is running so is compressor
  - However, some "periods of time" it is not necessary for compressor to pump air
    - This occurs when pressure in system is between a low of 80 psi to a high of 105 (in some, 125) psi
  - When pressure reaches high point, compressor goes into an "unloading" condition
    - Inlet valves remain open
    - Air is pumped back and forth between cylinders, not compressed
  - When pressure falls below low point
    - Compressor starts compressing and pumping air again
  - The compression cycle of the compressor is controlled by the air governor

Visual 9.8 Governor

Governor

- Designed to control when compressor will
  - Compress and pump air
  - Stop compressing air and go into "unloading" state
- The governor automatically maintains minimum and maximum reservoir air pressures
- Operation
  - When reservoir pressure reaches maximum pressure setting
    - Air pressure is sufficient enough to overcome a spring-loading device
    - Allows valve mechanism to move up
    - Permits exhaust stem to close exhaust valve and to open inlet valve

- Reservoir air pressure then passes through governor to operate compressor unloading mechanism
- Stops further compression of air by compressor
- When reservoir air pressure is reduced to minimum pressure setting
  - Air pressure is not strong enough to hold back spring loading device
    - The valve mechanism is activated
      - Closing inlet valve
      - Opening exhaust valve
    - Shuts off and exhausts air from compressor unloading mechanism compressor resumes compressing and pumping air

Air Reservoirs

- Function of air reservoir is two-fold
  - Provides a place for compressed air to be stored
  - Provides a location in the system where
    - Air heated by compression may be cooled
    - Condensed water vapor may be drained
- The volume of air stored in reservoirs must be adequate to handle volume of air used by brake chamnbers and auxiliary devices

Visual 9.9 Types of Reservoirs

Types of Reservoirs

- Reservoir design
- There are three basic construction designs for air reservoirs
  - Single compartment
  - Baffled
  - Multi compartment -- most will contain an integral check valve allowing air to flow in one direction only

Visual 9.10 Location of Reservoirs

Location of Reservoirs

- Most tractor-trailer systems will contain at least three reservoirs
  - Wet tank
    - Air from compressor goes directly to wet tank
    - Moisture present in air condenses and is drained
  - Dry tank
    - Air from wet tank is transferred to dry tank
    - Primary service tank for vehicle's air system
    - All pressure for operation of brakes is taken from dry tank
  - Trailer reservoir
    - Air tank located in trailer portion of vehicle
    - Used to supply air for
      - Trailer brakes
      - Emergency purposes

Visual 9.11 Safety Valves

Safety Valves

- Located in individual reservoir tanks
- If governor malfunctions and allows compressor to fill reservoir beyond a safe limit safety valve releases the excess pressure to protect the tank
- Valve usually set to go off when air pressure in reservoir reaches 150 psi.

Visual 9.12 One-Way Check Valve

One-Way Check Valve

- Located in air lines between wet and dry tank
- Prevents air from flowing backward into wet tank and through ruptured line in case of an emergency

Reservoir Drainage Valve

- Located at bottom of air reservoirs
- There are two types

Visual 9.13 Manual Reservoir Draining Valve

Manual Reservoir Draining Valve

- Must be opened manually
- Allows moisture that has accumulated to drain from tank

Visual 9.14 Automatic Moisture Ejectors

Automatic Moisture Ejectors

- Requires no manual assistance (however, can be activated manually)
  - Ejects moisture and contaminants which have collected in the sump portion of ejector

- Some reservoir systems contain either an alcohol evaporator and/or air dryers and/or after cooler

Visual 9.15 Alcohol Evaporator

Alcohol Evaporators

- Puts vaporized alcohol into vehicle's air system as an aid in preventing freeze ups
- Operation
  - Tubing from evaporator is connected to compressor intake
  - Air enters alcohol evaporator
    - Passes through tube which is immersed in alcohol
    - Air passing through alcohol causes it to bubble
    - Vapor formed by bubbling drawn into compressor intake and then into air brake system

  - Daily reservoir drainage is still required
  - Alcohol level should be checked daily

Visual 9.16 Air Dryers and After Coolers

Air Dryers and After Coolers

- Both designed to remove water and other contaminants from air coming from compressor
- Air Dryer Operation
  - Air from compressor enters dryer
    - Flows through a drying bed and an oil filter
    - Is then discharged to air reservoir
  - Dryer expells air from itself during every compression cycle
- After Cooler Operation
  - Air from compressor enter aftercooler
    - Air is forced to change direction within it several times
    - As direction changes it causes water droplets to form and fall out
  - Air is then discharged to air reservoir

Visual 9.17 Treadle Valve

Treadle Valve

- Also called a foot valve
- Treadle valve is a
  - Foot-operated
  - Air pressure regulating valve
- It is designed to allow driver to apply amount of air pressure to brake system necessary to stop vehicle
- Distance treadle is depressed determines amount of air pressure that will be applied
- Maximum application will not exceed pressure in the reservoir
- Releasing treadle releases brakes
- Operation
  - When treadle valve is depressed
    - Piston in valve moves downward contacting exhaust port, closing it
    - Continued piston movement opens inlet port allowing air to flow from reservoir through brake lines to brake chambers
    - Further depression allows more air to flow from reservoir
  - When treadle valve is released
    - Downward force on piston decreases
    - Piston moves upward opening exhaust valve and releasing brakes

Visual 9.18 Independent Trailer Brake Control Valve

Trailer Brake Control Valve

- Trailer brake valve is a hand-operated valve located in tractor cab
- Provides brake application to trailer unit only
  - Allows driver to independently control amount of appalication air to be direct to trailer brakes

Valuable under adverse conditions when it is desirable to
    Apply trailer brakes, without
    Applying tractor brakes

NOTE: **NEVER** attempt to use this valve for parking the vehicle

Visual 9.19 Tractor Protection Valve

Tractor Protection Valve

- Valve usually mounted behind cab of tractor
- It protects tractor air brake system
    - Under trailer breakaway conditions
    - When severe leakage develops in tractor or trailer
- Works in conjunction with a control valve located in tractor cab
    - Allows driver to manually control tractor protection valve
- Valve also operates automatially
- Operation
    - Trailer service and emergency lines pass through tractor protection valve
    - When control valve is in normal position, service and emergency braking functions of tractor and trailer are normal
    - When control valve is in emergency position
        - Trailer emergency line is vented to atmosphere through exhaust port in tractor protection valve
        - Trailer air brake lines are closed off on the tractor at tractor protection valve
    - This causes two things to happen
        - An emergency application of trailer brakes
        - Prevents air from being lost from tractor's system when airlines are disconnected or damaged
    - This can be accomplished
        - Manually by driver moving control valve to emergency position
        - Automatically when a dramatic air loss is detected by tractor protection valve, even though control valve is in normal position
        - Automatic action by tractor protection valve normally will occur only after driver has been warned by the low air pressure warning valve

Visual 9.20 Emergency or Trailer Air Supply Control Valve

Emergency or Trailer Air Supply Control Valve

- This valve is located on the control panel of tractor cab
- It is normally
    - A push-pull-type valve
    - Painted red
    - Octagon in shape
- This valve
    - Controls air supply to trailer reservoir
    - Provides a means of automatically protecting tractor air brake system in the event of air pressure loss in system

- Operation
  - When valve is opened (some systems, valve is open when it is pulled out and some, it's open when it is pushed in)
    - Check valve is unseated
    - Main reservior air pressure is
      - Allowed to flow through valve
      - Piped to tractor-protection valve through emergency air lines to relay emergency valve
        - Charges trailer air reservoir

  - The valve is spring loaded
  - It will be held in open position as long as pressure in valve is approximately 45 psi
  - If pressure drops below 45 psi
    - Spring-loaded plunger will move automatically, opening exhaust port conversely system normally must have 55 psi before valve will stay open when pushed in
  - The valve must be open for all normal operations with a trailer

NOTE: **NEVER** attempt to use this valve for parking the vehicle

Visual 9.21 Front Brake Limiting Valve

Front Brake Limiting Valve

- Limiting valve is mounted to either a
  - Bracket
  - Front crossmember or
  - Side rail near front axle
- Is found only on tractors having brakes on the front axle
- Its purpose is to limit amount of braking applied to front axle brakes under conditions where "locking up" the front brakes might adversely affect driver's ability to safely steer vehicle
- The valve allows driver to reduce front axle braking pressure to approximately 50 percent pressure applied to other axles of vehicle
- Valve is usually controlled by a two-way switch mounted on the dashboard of cab
- Switch will have two positions
  - Dry road
  - Slippery road
- When valve is in dry-road position
  - Limiting valve is not in operation
  - Brakes can apply with full force
- When valve is in slippery-road position
  - Limiting valve is in full operation
  - Limits pressure to front brakes
- Front brake limiting valve contains
  - One inlet port connected to treadle valve, and a control port connected to the two-way switch in cab
  - Delivery port--connected to brake chambers
  - Exhaust port--provides a place for delivered air to escape as the supply port pressure is reduced

  - Piston
    - Moves up and down in valve
    - Opens and closes valve ports
- Operation
  - Dry-road position
    - Inlet ports are open
    - Exhuast ports closed
    - Air has free passage through valve
    - Treadle valve application is made
      - Air enters both inlet ports
      - Piston is forced down closing exhaust port
      - Air passes through and out to brake chambers

  - Slippery road position
    - Valve is off
    - Inlet valve connected to two-way control valve is closed
    - Inlet valve connected to treadle valve is open
    - Exhaust valve is open
    - When treadle valve application is made
      - Air enters valve at top of inlet port only (connected to treadle valve)
      - Air is stopped at two-way control valve
      - Pressure is reduced limiting brake application

Visual 9.22 Stop Lamp Switch

Stop Lamp Switch

- Switch is located in service air line between treadle valve and brake chambers
- It activates stop lamps to warn following vehicles that you are
  - Reducing vehicle speed
  - Stopping
  - Switch contains
  - Two electrical connections
  - Diaphragm or piston or both
- Operation
  - Is an air-operated electrical switch connected to stop lights
  - Allows electricity to flow to stop lights
- When brakes are released
  - Diaphragm goes down
  - Points open, electrical connection broken
  - Stop lamp goes off
- Some vehicles have a light on the dash of cab which
  - Goes on when brake lights go on
  - Lets driver know stop lights are operating

Visual 9.23 Parking Brake Valves

Parking Brake Valve(s)

- Air brake systems will have one, and sometimes two, parking brake valves
  - System parking brake valve to properly park the complete vehicle
    - Valve is located on control panel in tractor cab

- Is usually
    - A push-pull type
    - Yellow colored
    - Diamond shaped
- Valve is to be used for parking only
- This valve can be operated either by pushing or pulling (depending on type)
- It may be operated manually, however

- When pressure in air system falls below 45 psi will go on automatically
    - Releasing air in trailer supply line
    - Applying brakes
- Low air warning device will activate when air pressure in system falls below 60 psi (this gives driver warning before a full brake application on trailer takes place)
- In order to charge trailer air reservoir
    - "System Park" valve must be in the "brake released" position
    - This valve overrides the trailer air supply valve

"Tractor only" parking brake valve

- Valve is also located on control panel in tractor cab
- Is usually
    - A push-pull type valve
    - Blue in color
    - Round shaped
- Is only available if tractor is equipped with "spring loaded" type parking brakes
- Can be activated by either pushing or pulling, depending upon type of design
- Can be applied while charging air trailer air system

Visual 9.24 Air Reservoir Pressure Gauge

Air Reservoir Pressure Gauge

- Gauge is
    - Located on dash panel in tractor cab
    - Calibrated in 10 psi increments from 0 to 150 psi
    - Usually labeled "Air"
- Provides a means of checking available air pressure in both the tractor and trailer reservoirs
- On a dual circuit system the gauge contains two pointers, normally of contrasting colors
    - One pointer registers air pressure in one system
    - The other registers pressure in the other
- Either pointer should not fall below 60 psi while vehicle is moving

Visual 9.25 Air Application Gauge

Air Application Gauge

- Gauge is:
    - Located in tractor cab
    - Mechanically operated

  - Calibrated in 10 psi increments from 0 to 150
  - Usually labeled "Brake Air" on gauge
- Provides a means of checking the delivery air pressure to brakes during brake application
- Operation
  - When air brake pedal is depressed, gauge pointer registers amount of air pressure being delivered to the front and rear air systems through
    - Air brake application valve to
    - Air brake chambers

Visual 9.26 Low Air Pressure Warning Devices

Low Air Pressure Warning Device

- The warning device may be in the form of a
  - Light or warning buzzer (alarm)
  - Drop arm (wig-wag) or
  - A combination of the three
- Device is located in tractor cab
- Is designed to warn driver when air pressure in any service air reservoir(s) drops below 60 psi when ignition is on
- When the low air warning device comes on while driving
  - Pull over **immediately**
  - Bring vechicle to a stop
  - Have system repaired before proceeding

Visual 9.27 Service and Emergency Air Lines

Service and Emergency Air Lines

- Every air brake system will have two types of air lines
  - Service - also called control line
  - Emergency - also called supply line
- Service lines are used in normal braking to transfer compressed air to the trailer brake chambers
- When treadle valve is depressed
  - Air is sent from dry tank through service line to brake chambers
  - Brakes are applied
- Service lines are charged with air only when a brake application is made (either with treadle valve or hand valve)
- Emergency lines on the other hand are always charged with air
- They are used for
  - Charging trailer reservoir with air
  - Emergency trailer brake applications

Visual 9.28 Quick Release Valve

Quick Release Valve

- Is located close to brake chambers
- It usually acts as a T-junction between brake chambers on the axles
- This valve
  - Exhausts brake chamber air pressure

- Speeds up brake release by reducing distance air would have to travel back to the treadle valve exhaust port

- Operation
  - Is operated by air pressure from treadle valve entering inlet port
  - Air forces a diaphragm against the exhaust port seat
    - Air goes through valve by passing around edges of diaphragm and out side connections to brake chambers
  - When treadle valve is released
    - Diaphragm is lifted off of exhaust port
    - Air is allowed to escape directly through the exhaust port to atmosphere

Visual 9.29 Relay Valve

Relay Valve

- Is generally substituted for a quick-release valve when dual axles are used
- Normally
  - Air pressure waits in reservoir until it is needed
  - When driver depresses treadle valve air pressure rushes from reservoir, through lines, to brake chambers, via relay valve
- However, when relay valve is installed
  - Air pressure doesn't wait until treadle valve is depressed to leave reservoir d to escape directly through the exhaust port
  - It constantly fills lines and waits in the relay valve apparatus
- This valve does two things
  - Makes air pressure available much closer to the point of usage
    - Producing faster brake applications
    - Reducing stopping distance
  - As with a quick-release valve, it allows pressure to release quickly, because
    - Air can be released at relay valve
    - Does not have to travel back to treadle valve exhaust port

Visual 9.30 Brake Chambers

Brake Chambers

- A brake chamber is usually mounted on the axle near wheel that is to be equipped with a brake
- Brake chambers
  - Convert energy of compressed air into mechanical force and motion
  - Force brake shoes against drums in a brake application
- Brake chambers consist of
  - Two disked plates -- either bolted or clamped together
  - A fabric diaphragm
    - May be bolted or clamped into place inside chamber depending upon type of plates
    - May be made of rubber or neoprene and nylon or various other materials

  - A push rod and return spring -- transfers motion of diaphragm to brake shoes
  - A rubber boot -- keeps dirt and water from entering brake chamber

- Operation
  - Air pressure is admitted to brake chambere through air lines when treadle valve is depressed
  - Compressed air moves diaphragm, push rod and slack adjuster toward position applying brakes
- As treadle valve is released
  - Air pressure is exhausted from brake chamber
  - Spring returns diaphragm, push rod and slack adjuster to normal position, releasing the brakes

NOTE: The next section, S-cam versus wedge-type brakes, will go into more depth about operation of the different types of brake chambers)

Slack Adjusters

- Slack adjusters are attached to the brake chamber push rod
- They provide a quick and easy method of adjusting brakes to compensate for lining wear
- Slack adjusters may be adjusted either manually or automatically

Visual 9.31 Manual Slack Adjuster

Manual Slack Adjusters

- Manual slack adjusters consist of
  - Lever-type arm attached to brake
  - Chamber push rod by a clevis and pin
  - Worm gear and adjusting nut -- gear is splined to fit over cam shaft
  - Adjustments are made by
    - Turning adjusting nut, which in turn rotates the worm gear and cam shaft
    - This moves brake shoes closer to brake drum (compensating for lining wear)
    - As a result, push rod coming out of brake chamber does not have to travel as far for brakes to be applied
  - The most efficient brake action will be obtained when slack adjuster arm and push rod travel is held to a minimum

Visual 9.32 Automatic Slack Adjuster

Automatic Slack Adjuster

- There are basically two types
  - One type senses and adjusts on the basis of brake stroke or push rod travel
  - The other type adjusts for shoe-to-drum clearance by sensing pushrod travel and point of shoe-drum contact
- Automatic slack adjusters eliminate need
  - For mechanic to crawl underneath vehicle to measure push rod travel
  - To reset brakes by hand

This means
    More valuable road time for vehicle
    Reduced labor costs
Automatic slack adjusters
    Work while vehicle is operating
    Keep brakes in constant adjustment

Operation
    A spring clutch links drive wheel and sleeve to worm gear shaft
    As treadle valve is depressed
        Drive wheel rotates
        Spring grips both drive wheel sleeve and worm gear shaft
        Worm gear and shaft turn rotating camshaft applying brakes
    When treadle valve is released
        Spring slips on worm gear shaft and/or drive sleeve
        Anti reverse spring or friction in system prevents worm gear from returning to original position
        Shoes remain closer to drums, adjustment complete
    Spring clutch only turns worm gear until shoes contact brake drum so overadjustment does not occur
    Adjustment if necessary occurs each time brakes are applied
    Must periodically inspect to insure they are functioning properly and also to determine how much brake lining is left

Repeat Visual 9.31 Brake Drums

Brake Drums

Drums are
    Located on each end of vehicle's axles
    Made of varying thicknesses of iron or steel
Vehicle's wheels are bolted to drum
Drum and wheel rotate together
The braking mechanism is located inside drum (e.g., brake shoes and linings as well as actuating device)
Brake shoes and linings push against surface of drum producing friction which creates heat to stop vehicle
Heat generated by braking process
    Must be absorbed by brake drum
    Dissipated into atmosphere
Amount of heat drum is able to absorb depends upon thickness of iron or steel drum is made out of
The heavier (thicker) the brake drum, the more heat it can absorb, the more effective the braking
It is very important that the inside surface of the drum is smooth and uniform, not scored -- ridges cut into surface
Bell-mouthed -- sides flared, not straight
Threaded -- tiny nicks cut into surface
Hard spotted -- islands of steel that protrude from surface
All these conditions keep brake shoes from making complete contact with drum resulting in
        Erratic and unpredictable brake action
        Brakes squealing

Repeat Visual 9.31 Brake Shoes and Linings

Brake Shoes and Linings

- Located inside brake drums
- Linings made of asbestos or metal mineral fiber (new) are attached to brake shoes
- Each drum will contain two shoes with attached linings
- Linings are one of the friction elements in the drum brake process--the brake drum being the other element
- When brakes are applied
  - Brake shoes and attached linings are forced against inside surface of brake drum
  - Friction is created producing heat which slows rotation of brake drum, thus slowing vehicle
- Brake linings influence brake performance more than any other single component

Drum Brake Actuating Devices (S-Cam Versus Wedge Brakes)

Repeat Visual 9.31 S-Cam Actuated Drum Brake

S-Cam Acutated Drum Brake

- Location
  - Cam is located at end of cam shaft
  - Cam shaft is attached to slack adjuster
  - Slack adjuster is attached to diaphragm in brake chamber through a push rod
- Operation
  - Each cam actuated brake has two shoes with attached linings
    - Each shoe assembly pivots at one end
    - Has a roller that rides on cam at other end
  - When treadle valve is depressed
    - Air pressure is admitted to brake chamber
    - Compressed air pushes out against diaphragm
    - Diaphragm forces push rod out, moving lever arm of slack adjuster
    - Lever arm converts pushing motion of push rod into twisting motion of cam shaft
    - S-cam located on end of cam shaft is rotated
    - Rollers attached to brake shoe assembly and resting on S-cam
      - Move farther out on cam radius
      - Forcing brake shoe assembly against rotating brake drum
    - Friction created by lining contacting drum slows vehicle
  - When treadle valve is released
    - S-cam rotates back to original position
    - A return spring pulls brake shoe assemblies away from drum
- Adjustment
  - S-cam actuated brakes may be adjusted both manually and/or automatically

Visual 9.33 Wedge-Actuated Drum Brake

Wedge Actuated Drum Brake

- Description and location
- A wedge-actuated drum brake may have one or two actuating devices (wedges)

- The actuating device is composed of
    - A wedge-shaped piece of metal molded on the end of a push rod
    - Two cylindrical metal pistons or plungers
- Push rod is connected to diaphragm in brake chamber
- Plungers are attached to brake shoe assembly on one end and to rollers (which rest on wedge) at other end
- Single actuated version contains
    - One actuating device
    - Two brake shoe assemblies
        - Each shoe pivots at one end (similar to S-cam brake)
        - Attaches to piston or plunger at other end
- Double-actuated version contains
    - Two actuating devices
    - Two brake shoe assemblies
        - Shoes do not pivot at one end
        - Both ends of both shoes are attached to piston or plunger
- Operation
    - When treadle valve is depressed
        - Air enters brake chamber
        - Compressed air pushes diaphragm outward
        - Diaphragm forces push rod out
        - Wedge molded on end of push rod pushes against rollers attached to plungers
        - Plungers are forced outward pushing brake linings against drum
        - Friction created from linings contacting drum slow vehicle
    - When treadle valve is released
        - Air is expelled from brake chamber
        - Diaphragm returns to normal position
        - Push rod and wedge move back
        - Return springs pull the linings away from drum
- Adjustment
    - Most wedge-actuated drum brakes are automatically adjusted, internally

Trailer Brakes

- Trailer brakes are connected to tractor via
    - Standard straight air lines
    - Flexible (spring coil type) retractable air lines
- Selection of hose depends largely on amount of gap between cab and trailer
    - Standard conventional hose is
        - Less expensive
        - Sag proof
        - It is formed with
            - Smooth inner tube

- Two or more plies of high-strength nylon (or other material) braid
- It is the common and most logical choice for equipment with cab-to-trailer gaps of six feet or more

Coiled retractable hose is

- More resistant to abrasion
- Made with abrasion-resistant nylon which is considerably lighter than conventional hose
- It is highly popular where cab-to-trailer gap is less than 6 feet
- Its ability to extend or retract as required keeps "slack" lengths away from
  - Frame rails
  - Other areas where it could be damaged

Air lines need some sort of device to lend support

Federal safety regulations require that air brake hoses be secure against

- Rubbing
- Chafing
- Kinking
- Mechanical damage
- High-heat contact

Hose must also have sufficient length to protect it against normal trailer movement

There are three basic types of air hose keepers (supporters)

Visual 9.34 Bracket and Spring Air Hose Keeper

Bracket and Spring Air Hose Keeper

Bracket is normally mounted in center of cab over rear window

A spring attached to bracket wraps around hoses and gives support

Usually used when clearance between tractor and trailer is minimal

Because of space consideration, flexible spring coil air hoses are usually used with bracket and spring keepers

Visual 9.35 Pogo Stick Air Hose Keeper

Pogo Stick Air Hose Keeper

Usually mounted as close to back of cab as possible (i.e., a 6 inch clearance from cab usually permits stick to bend suitably during a turn)

Some sticks have

- Internal springs
- Flexible pivot connections
- Tube extensions

These additional items give more flexibility to stick

Hose support rings are attached to top of stick to hold air hoses

Pogo sticks usually require only standard straight air hoses

Visual 9.36 Slider Bar Air Hose Keeper

Slider Bar Air Hose Keeper

- Is a stainless steel bar mounted onto back of cab
- It has a
  - Nylon ring attached to a vinyl sheath spring with a quick-release clip and hose clamp
- This arrangement
  - Gives all space-saving advantages of bracket and springs
  - Has added advantage of permitting driver to make connections from either side without climbing up behind cab (major cause of truck injuries, especially during winter months when footing is uncertain)
- Hoses and cables are suspended high and out of the way
- Combination of sliding action and spring allows full extension of cables and hoses without chafing on cab or trailer
- Spring sheath also protects cab finish

Visual 9.37 Glad Hands

Glad Hands

- Glad Hands is the term used in reference to coupling device used to connect service and emergency air lines of trailer to tractor
- These couplers
  - Have a snap lock position
  - Air is sealed by an "O" ring
- Glad Hands are usually located to the rear, either at one side of the cab or the other
- This type of location
  - Eliminates necessity of climbing up behind cab to make connections
  - Is safer and saves time
- Some vehicles are equipped with "dummy" couplers
  - Are used when tractor is operating without trailer
  - Service and emergency air line gladhands attached to these couplers mounted on rear of cab
- Keeps lines from being damaged and keeps foreign matter out of the airlines
  - When vehicle is not equipped with "dummy" couplers
    - Glad hand of service line can be locked to glad hand of emerge line
    - This keeps
      - Water and dirt from entering unused lines

Tractor and Trailer Unit Coupled

- As discussed earlier
  - Trailer brakes are coupled to tractor braking system by using hands to connect both emergency and service air lines
  - Trailer unit has a reservoir of its own
    - Tank provides volume of air near trailer brake chambers normal and emergency braking
    - Is equipped with drain-cock as are main reservoirs on tractor

Both service and emergency air lines on the trailer are attached to relay emergency valve

Visual 9.38 Relay Emergency Valve

Relay Emergency Valve

- This valve is a
  - Pilot operated
  - Graduating directional control valve
- It can handle a high capacity of air and responds very rapidly
- All air coming into trailer brake system must pass through the relay emergency valve
- This valve serves several important operating functions
  - During normal operation
    - Relay emergency valve permits charging trailer reservoir to approximately same air pressure as is in tract or reservoirs
    - Serves as a relay valve
      - Relays air from trailer reservoir to trailer brake chambers during a brake application
      - Synchronizes trailer service brake air pressure and tractor service brake air pressure as service treadle valve on tractor is applied
      - Trailer brakes can also
        - Be applied independently of tractor brakes using hand controlled valve on tractor and relay emergency valve on trailer
- The emergency portion of the valve instantaneously applies full trailer reservoir air pressure to the brake chambers when
  - Trailer becomes disconnected from tractor, rupturing air lines
  - Emergency air line pressure is vented to atmosphere via trailer supply valve
  - When tractor air supply or the emergency line pressure is reduced to approximately 45 psi due to leakage or conditions other than the above
    - A graduated trailer brake chamber application will occur
    - Each one-pound reduction in emergency line pressue results in a four-pound increase in trailer brake chamber pressure
  - This gradual application of brakes forewarns driver that full emergency trailer brake chamber application is about to take place
  - Operation
    - Normal brake application
      - Air from treadle valve application
        - Enters relay emergency valve
        - Depresses a diaphragm
        - Opens inlet valve permitting air to go direcly from trailer reservoir through relay emergency valve to trailer brake chambers
      - When balanced pressure is reached above and below diaphra a return spring moves diaphragm up, closing inlet valve
      - Air is exhausted from line between brake valve and relay emergency valve

- Emergency Application
  - When air has been lost or exhausted from emergency line
    - Emergency part of relay emergency valve goes into operation
      - Upper part of valve seats and seals system
      - Lower part of valve unseats permitting full air pressure from trailer reservoir to go to trailer brake chambers applying brakes

The Emergency System

- The basic tractor-trailer braking system is operated by air
- Air provides enough pressure against mechanical linkages to
  - Bring brake shoes in contact with drums thus stopping or slowing vehicle
- In other words, tractor-trailers must have "enough air pressure" before regular service brakes will work
- If air pressure drops below a certain level you will not have any brakes
- Too little air = no service brakes
- The emergency system is designed to
  - Detect when air pressure drops
  - Activate brakes when pressure drops below a specified danger level

Visual 9.39 Fail-Safe Spring Brakes

Fail Safe Spring Brakes

- Most tractor-trailers are equipped with fail-safe emergency brakes
- Almost all fail-safe systems are spring operated
- Fail-safe systems were designed to serve three basic purposes:
  - To eliminate possibility of runaway vehicles when they are left unattended and air in system bleeds off
  - To provide an emergency means of applying brakes in the event of air system failure while vehicle is in operation
  - To provide a positive parking brake
- Spring-operated systems consist of a
  - Service portion which contains the service diaphragm and spring
  - Emergency portion containing emergency spring and piston
- The units have two air connections
  - One for service line
  - The other for emergency and parking line

How Spring Brakes Work

- The emergency airline provides full tank air pressure under piston
- Keeps emergency spring compressed
- When pressure in system drops below a predetermined amount (normally 45 psi)
  - Lack of air pressure lets spring expand
  - Spring forces piston outward
  - Brakes are applied
- There are three basic designs of spring brake systems

Integral Type Spring Brake

- Brake chamber is replaced with an entire unit
- It incorporates a
  - Brake chamber diaphragm
  - Spring loading arrangement
  - Piston
  - Mounting flange

Remote Type Spring Brake

- Designed to connect to slack adjusters
- Brake chambers and slack adjusters are not disturbed
- Unit is mounted as a separate component and is linked or attached to slack adjusters

"Piggy-Back" Type Spring Brake

- Top of brake chamber is removed and replaced with a unit that contains
  - Spring arrangement
  - Piston for adjusting slack adjuster

"Caution"

- Springs in fail-safe units are very powerful
- Never attempt to work on spring brakes until you have had full training on the subject
- Do not disassemble a unit until all necessary precautions have been taken to prevent it from exploding
- If accidentally released, spring is powerful enough to go through a wall of a building

Emergency Applications

What happens to the air brake system when the following four situations occur

Visual 9.40 Trailer Breaks Away From the Tractor

Trailer Breaks Away From Tractor

- This results in a separation of service and emergency air lines
- Sudden loss of air pressure in emergency line "triggers" Relay Emergency Valve
- This causes
  - Trailer reservoir to release all its air directly to trailer brake chambers
  - Trailer brakes are applied
- Loss of pressure in emergency line also causes
  - Emergency valve to automatically close
  - Tractor protection valve prevents loss of air in tractor system
- Tractor or brakes remain operable, allowing tractor to be stopped
- Trailer brakes will remain applied until
  - Pressure in trailer reservoir and lines is drained off
  - Emergency line is repaired and system is recharged

Visual 9.41 Service Line Ruptures

Service Line Rupture

- Nothing will happen when the service line ruptures (or if glad hands of service line become uncoupled) until a brake application is made (either with treadle valve or hand valve)
- When a brake application is made:
  - Air is directed through service line to tractor protection valve
  - Tractor protection valve directs air through valve into service line
  - Since service line is ruptured
    - Air escapes rapidly
    - Causes drop in pressure in emergency line
  - Pressure loss in emergency line triggers relay emergency valve
    - Trailer reservoir air is released to trailer brake chambers
    - Trailer brakes are placed in an emergency situation
  - Loss of pressure in emergency line causes emergency valve to close
  - Trailer brakes may be released by opening emergency valve recharging trailer system or by draining the trailer reservoir

Visual 9.42 Emergency Air Line Ruptures

Emergency Line Rupture

- Rupture of emergency line (or an uncoupling of emergency line glad hands) will result in
  - Rapid loss of pressure in emergency line between
    - Emergency valve
    - Relay emergency valve
- This results in "triggering" emergency action of relay emergency valve
  - Emergency valve closes
  - Trailer reservoir air is released to trailer brakes, braking trailer
- Tractor protection valve prevents rupture from draining all of air pressure from tractor system

Loss of Main Air Reservoir Pressure on Tractor

- Rupture of discharge line from compressor to wet tank would result in
  - Loss of main reservoir air pressure
  - One-way check valve between wet and dry tank would prevent loss of air from dry tank
  - Low pressure switch will activate warning device (buzzer, light, drop arm) when main reservoir air pressure drops below approximately 60 p.s.i.
  - There is sufficient reservoir air pressure in dry tank for a limited number of brake applications

- If main reservoir pressure on tractor falls below 60 p.s.i. due to
  - Compressor failure
  - Excessive leakage on tractor
- Low reservoir air warning device will be activated and continue to operate until pressure is built up
- The relay emergency valve on trailer has a "no-bleed back" feature which
  - Prevents air loss of trailer reservoir air
  - Maintains trailer air for emergency braking

How to release spring brakes

- As discussed earlier, spring brakes are applied when compressed air is exhausted from brake chamber
- Some vehicles are equpped with an additional air reservoir tank
- This tank is called an "Emergency Release Tank"
  - It holds a limited reserve of air pressure
  - Is used to release spring brakes in an emergency (i.e., spring brakes are applied in middle of roadway, blocking traffic) long enough for vehicle to be moved
- To do this
  - Driver must press an emergency release button in cab and hold the regular control open
  - When buttons are released, spring brakes will automatically re-apply
- If vehicle is not equipped with the special release tank, brakes can be released mechanically by "winding them off"

Caution: Before releasing spring brakes mechanically, **always** chock wheels to keep vehicle from rolling. **Never** lay in the path of wheels when releasing brakes

Visual 9.43 Releasing "Stopgard Type" Spring Brakes

Releasing Stopgard Type Spring Brakes

- Turn bolt running through brake
- Chamber approximately 30 turns counterclockwise to compress spring
- May be necessary to
  - Remove a lock plate and stud first to gain access to head of bolt

Visual 9.44 Releasing "Anchorlok" Spring Brakes

Releasing Anchorlok Type Spring Brakes

- Remove rubber cap from rear of brake chamber
- Insert release stud with nut and flat washer through chamber (where rubber cap was removed) and turn stud 1/4 turn clockwise
- Using wrench turn stud nut down several turns against resistance to release brake

Parking Brakes

- Parking brakes are usually either
  - Mechanically operated or
  - Spring actuated
- Some systems use an air assist to operate a mechanical unit

Mechanical Parking Brakes

- Most mechanical units are of the internal expansion type
  - Is to be set only after vehicle is brought to a complete stop (except in the case of an emergency)
  - Is not designed for regular use in place of service brakes
- Brake is applied and released by
  - A single control handle in cab
  - A flexible cable extends from control handle to brake
- The brake assembly is
  - Mounted at rear of transmission
  - If cam operated by a single lever, controlled by a bell crank and linkage
- Brake consists of
  - Brake drum
  - Shoes and linings
  - Flat actuating cam
  - Adjusting wheel
- Drum is attached to and revolves with the drive shaft
- When brake is applied in cab
  - Cable attached to control handle activates bellcrank and linkage
  - It in turn moves on actuating lever which forces brake linings against drum preventing drive shaft from moving
- Brake must be manually adjusted
- Can be used on vehicles equipped with manual or automatic transmissions

Spring-Actuated (fail-safe units)

- Spring brakes are used as a vehicle's emergency as well as parking brake system
- See discussion of Emergency System

Drum Versus Disk Brakes

- Drum brakes as discussed earlier consist of a drum which contains brake shoes and linings located inside drum
- The drum is attached to axle
- The wheel is mounted on the drum
- Wheel rotation is slowed and eventually stopped by
  - Brake shoes pressing out against drum
  - Linings attached to shoes creating friction producing heat which stops vehicle

Visual 9.45 Disk Brakes

Disk Brakes

- Disk brakes consist of
  - Circular metal disk attached to axle

    - Disk is sometimes solid metal
    - Others are vented metal
- A caliper (usually sliding) fits over disk and contains
    - Two brake shoes with attached linings
    - A mechanism that multiplies force usually either
        - Power screw
        - Helical cam
    - Automatic slack adjusters
    - Air chambers
- The disk brake operates in the manner of a C clamp
- EXAMPLE: (Power Screw Type)
    - A piston is attached to brake shoe on inside of disk
    - Power screw works like a C clamp
    - Screw shaft is rotated
    - Screw forces piston to advance
    - Brake lining attached to shoe on inside of disk is forced against disk
    - This causes caliper to slide
    - Outside brake shoe and lining is pulled against disk
    - Equal pressure is applied on both sides of disk in a clamping motion
    - The power screw
        - Is a simple force-multiplier design
        - Is favored by several disk brake manufacturers
    - Force multipliers in an air disk brake, boost output force from brake chamber 6 to 20 times to the clamp-force level needed stop a heavy-duty truck

Advantages and Disadvantages of Drum and Disk Brakes

Brake Fade

- Excessive heat causes drums to
    - Expand and thus
    - Move farther away from brake linings, which reduces friction
- Resulting in brake fade
- However, a drum brake is a "smart" brake
    - Its fade characteristics can give an alert driver some warning that brakes are being used too hard or improper
    - Drum brakes can fade and still recover to provide braking afterwards (unless fading is very extreme)
    - Excessive heat in disk brakes on the other hand causes
        - Disks to expand
        - Move closer to brake lining in caliper
    - Resulting in little if any brake fade
    - However
        - Unlike drum brakes which absorb and dissipate heat
        - Disk brakes must throw heat off very rapidly
    - When disk is buried inside a set of dual wheels
        - Very little air circulation is available
        - Throwing heat off becomes a problem
    - This results in reduced lining life

- Disk brakes will keep right on working up to the point where they destroy themselves without any warning to the driver that the condition is iminent

Economy and Maintenance

- Disk brakes cost 25 percent-35 percent more than comparable drum brakes
- However, they may reduce the GVW of a drum-braked 5-axle tractor-trailer by as much as 626 pounds
- This will result in an increased payload hauling capacity
- Maintenance is simpler in a disk-braked vehicle because
  - There are fewer moving parts
  - Disks are easier to get at
- However:
  - Lining life is drastically reduced
  - Linings must be installed more frequently

Water Recovery

- Drums by their design
  - Retain water
  - Take a longer time to get rid of water
- In disk brakes, water is thrown or wiped off disk's surface almost immediately

Brake Response

- Disk brakes offer
  - A smoother, quicker and more even response
  - Reduced variation in braking force from side to side (e.g., improved directional stability)
- Drum brakes
  - Will not respond as fast as disk brakes
  - Typically vary in braking force from side to side (under certain conditions) more than disk type does

Compatability

- Since response time of drum and disk brakes differ and because of disk brakes' characteristics some problems may occur

EXAMPLE:
- Tractor is equipped with disk brakes
- Trailer with drum brakes
- Trailer's drum brakes produce considerably more torque than tractors' disk brakes at low speeds (where most stops are made)
- Trailer brakes will be doing more work than tractors, consequently will wear out faster
  - Response time, tractor brakes on before trailer creates problems also (compatability problems in braking system will be discussed later)

The Federal Motor Vehicle Safety Standard 121 Air Brake System

- In January 1975 the National Highway Traffic Safety Administration's (NHTSA) new rules regarding braking systems of trucks and buses became effective
- The standard was later revised
- Many new changes in the braking system were required by the 121 Rules

Some of the major requirements were
- Shorter stopping distances
  - Initially trucks were required to stop within 257 feet on dry pavement traveling 60 mph while staying within a 12-foot wide lane
  - Distance was later revised upward to 293 feet

An Anti-Skid System

- Purpose of the anti-skid system was to control wheel lock-up
- System activates when driver applies pressure on brake pedal severe enough to lock wheels
- Before 121 brakes, a driver in a must-stop situation had to pump or modulate the brakes to keep his wheels from locking up
- The makers of 121 brakes took this well-known practice of pumping the brakes and packaged it into a computer-operated brake system
- This system is capable of pumping the brakes three to five times per second faster than any human being possibly could and more importantly does it on the wheel(s) that are in imminent danger of locking up

Visual 9.46 Typical 121 Dual Air Brake System

Typical 121 Brake A Dual Air Supply System

- System is made up of two interconnected systems which normally function as one
- If one system is lost, the other system allows you to stop rig
- To do this, the 121 system has:
  - Three air reservoirs for service brakes of which
  - One is a supply tank
  - Two are service tanks (one for front axle; the other for rear axle)
- The supply tank holds the air and feeds it to the dual service tanks
- Both service tanks work as a single unit until there is a failure on one side of system
- Each half of system is isolated from the other by a double check valve so that a failure on one side will not create a failure on the other
- The driver will know there has been a failure in one side of system will be a drop in air pressure registered on the dual needled air reservoir pressure gauge in cab and the low air warning device will activate
- So every rig equipped with a 121 braking system will typically have
  - Front axle brakes - one circuit
  - Rear axle brakes - one circuit
  - Trailer brakes - both circuits
- All three are required to stop vehicle within the specified 121 mandated stopping distance

- Each can operate independently of the other, however, when needed to stop rig
  - Brake application and release times
    - The 121 standard required
      - "With an initial service reservoirs pressure of 100 psi, each brake chamber shall, when measured from the time the driver depresses pedal, reach 60 psi in not more than .45 second"
    - Release time
      - Required a complete brake release in .55 second
  - Many design changes had to take place
    - Air supply had to be enlarged
    - New valves had to be designed and installed
    - The material make up of brake lining had to be changed (high friction linings were installed)
    - Stronger front axles were needed
- Of the 121 brake requirements discussed, only brake application and release time requirements remain today. Nevertheless, today's equipment, in varying degrees, reflects the 121 standard.

Proper Braking Techniques

Treadle Valve Application for

Ordinary Stops

- Apply treadle valve more fully than required, then
- Immediately start letting up on valve
- As road speed decreases, pressure on treadle valve should decrease so that
- By the time vehicle comes to a stop, you've stopped depressing, i.e., you've released the treadle valve
- In other words
  - The initial brake pressure will be much higher than the continuous pressure required to maintain the normal rate of deceleration

Emergency Stops on Dry Pavement

- Two emergency braking techniques can be used
  - Controlled braking
  - "Stab" braking
- Controlled braking
  - Apply pressure on treadle valve just short of a wheel lock up
  - Maintain steady pressure on treadle valve till vehicle comes to a stop
- "Stab" braking
  - Apply treadle valve fully
  - Release partially when wheels lock (releasing valve avoids skidding due to wheel(s) lockup)
  - Reapply pressure on valve when wheels start rolling again
  - Repeat technique until vehicle slows sufficiently for a safe stop

- Between each application of treadle valve, allow time for wheels to roll again
  - Reapplying brakes too quickly can result in a skid
  - Generally takes 1/2 to 1 second for wheels to start rolling

NOTE: Additional information may be found in Section 3, Unit 3.2, Emergency Maneuvers

Emergency Stops on Slippery Pavement

- If emergency stop is required on slippery pavement, use "stab" braking techniques as described above

NOTE: Additional information may be found in Section 3, Unit 3.2, Emergency Manuevers, as well as Unit 3.3, Skid Control and Recovery

Applying Independent Trailer Brake (Hand Valve)

- The trailer brake is very difficult to apply
  - Very easy to get too much pressure or
  - Too little pressure
- It requires driver to take one hand off of steering wheel
  - In bad weather this may cause handling problems
- If braking system in vehicle is not dynamically balanced (tractor brakes on before trailer brakes) it is sometimes believed that applying trailer valve before applying treadle valve will help prevent tractor jackknifing
  - In some cases this may be true, however
      - Applying correct amount of pressure to trailer brakes is extremely difficult to judge (too much pressure could result in a trailer jackknife)
      - Taking one hand off steering wheel for any length of time can be hazardous
    - Driver is better off applying treadle valve and leaving trailer brake valve (hand valve) alone

Left Foot Braking

- All braking with treadle valve should be done with right foot
- Braking with left foot
  - Increases driver reaction time
  - Increases possibility driver may hit wrong pedal

Braking Technique for Long Steep Downgrades

- Continuous versus "snub or fan" braking
  - Myth: Applying brakes intermittently (fanning or snubbing) allows air to circulate around brakes and keep them cool
  - Fact: Light continuous brake pressure applied to brakes on a vehicle descending a grade in the proper gear results in
    - Less heat build up
    - Little if any brake fade
    - Brakes that will function at the bottom of the grade

NOTE: Additional information can be found in Section 2, Unit 2.6, Extreme Driving Conditions

- Snubbing or fanning brakes (on-again off-again application)
  - Requires heavier pressure when brakes are applied
  - Generates tremendous heat (up to 1,300 degrees)
  - Time between applications is not sufficient to allow brakes to cool
- Proper technique
  - Shift vehicle down to proper gear (usually same gear used to ascend grade)
  - Apply light continuous pressure all the way down grade
- The brake system is a heat exchange machine
  - If only a little energy is put into the system (light continuous pressure instead of heavy intermittent pressure) then
  - The system only has a little energy (heat) to get rid of

How to Park Vehicle When

Brake Drums are Extremely Hot

- Do not set parking brake
- This will
  - Warp drums
  - Destroy brakes
- Proper technique
  - Try to stop on level surface, shut down engine
  - Place transmission in lowest gear
  - Chock vehicle's wheels
  - Wait for brakes to cool before setting them

Brake Shoes and Drums are Wet

- Again, do not set parking brake
- Linings will freeze to drum and will have to be replaced
- Drums may be scored or damaged
- Proper technique
  - Try to stop on level surface, shut down engine
  - Place transmission in lowest gear
  - Chock wheels
- Better yet try to anticipate this situation and "drag" brakes to dry them out prior to parking

Proper Operation of Air Brake System

Dynamic Balance of Air Brake System

- A dynamically balanced brake system will react in the following way:
  - All brake chambers on trailer will receive air first (only by a split fraction of a second)
  - Next the brake chambers on the tractor will then receive air
- It is very important that there be very little difference in brake application times between tractor and trailer
- The obvious problem that confronts the driver today is the mixing of incompatible equipment
- Most trailers last longer than tractors. Therefore, a lot of pre-121 trailers (1975) are still in operation today

When a new tractor is paired with an old trailer (if adjustments are not made) trouble can occur

EXAMPLE: Tractor equipped with
    - New air disk brakes or drum brakes with new high-friction linings (aggressive fast-applying)
  - Trailer equipped with
    - Old drum brakes with low friction linings
- Result:
  - When treadle valve is applied, tractor brakes react quicker than trailer brakes, thus braking occurs first on the tractor then the trailer
- Anything over .20 second (tractor on before trailer) is potentially hazardous
  - The danger increases with speed (e.g., at 30 mph it isn't very dangerous; at 55 mph it is)
  - It is compounded by hills, mountains, ice, rain, snow, curves, etc.

Imbalance of brake timing between tractor and trailer can be a contributing factor to jackknife accidents

If trailer brakes have just been adjusted and they still feel like they need adjusting, chances are they are out of balance with the tractor brakes

Another problem exists, in uneven braking force from side to side

This can occur when
  - Brake on one side of axle is manually adjusted differently than brake on the other side of axle or
  - New shoes and linings have been installed on one end of axle and not the other

As with the tractor-trailer imbalance, uneven braking force from side to side becomes more dangerous at higher speeds, and when operating in inclement weather

Visual 9.47 Total Stopping Distance

Total Stopping Distance

Stopping distance is composed of five different factors
  - Vehicle speed
  - Road conditions
  - Perception plus reaction distance (driver's see-think-act time)
  - Brake lag (air transmission time)
  - Effective braking distance

For any given vehicle speed: Driver Perception Reaction Distance + Air Transmission Distance + Effective Braking Distance = Total Stopping Distance

EXAMPLE: A vehicle traveling 20 mph on dry pavement
  - Will require approximately 44 feet for driver's perception and reaction time
  - An additional 12 feet for the air transmission time
  - And an additional 20 feet will be required for the actual braking distance used by the vehicle
- Total stopping distance at 20 mph on dry pavement is approximately 76 feet

When road conditions are wet, icy, or slippery, the effective braking distance will increase, thus increasing total stopping distance

NOTE: As the speed doubles, totally stopping distance more than doubles. Also note that the stopping distances on this chart are absolute minimums, made under the best of special testing conditions. This is the reason that these distances appear to conflict with those shown in Unit 2.3. It must be stressed that under actual daily operating conditions the stopping distances shown in Unit 2.3 will be more realistic than these full application test stop distances are.

Brake Fade

- Is caused by heat generated during a "severe" stop or after a closely spaced series of "hard" brake applications
  - If brake temperatures get too high and exceed the designed capacity of the drums heat absorbing/dissapating capabilities
  - Drums expand, moving farther away from brake shoe linings
  - Causes brake shoe to travel farther to contact drum
  - When travel limits of brake shoes are reached and drum continues to expand, vehicle is then operating with no service brakes
- How to recognize brake fade
  - Fading has generally occurred
    - When driver becomes aware of needing more pressure on the treadle valve to stop vehicle in a given distance
- When and where does it occur?
  - Brake fade can happen
    - In all seasons
    - On flat land
    - In mountainous terrain
    - In cities or open country
  - Brake linings and drums have different thermal capacities (can withstand and absorb different degrees of heat)
  - Low thermal-capacity brakes produce fade very rapidly--particularly if the brakes' cooling ability is restricted
    - Can only absorb limited amounts of heat
  - High thermal capacity brakes will fade only under extreme heat
    - Can absorb great amounts of heat
  - When a braking system is exposed to heat greater than it is capable of absorbing and dissipating, brake fade and/or failure will result
- Brake fade is synonomous with increased
  - Speed
  - Weight
  - Temperature
- As these three conditions go up so does the problem of brake fade

Auxiliary Brakes or Speed Retarders

Visual 9.48 Auxiliary Brakes or Speed Retarders

- Types of speed retarders
  - There are four basic types of speed retarders
  - Each type has its place in the trucking industry
  - The four classifications are as follows:

Exhaust Brakes

- Considered the simplest form of heavy-vehicle retarder
- Contains a butterfly valve installed in exhaust manifold, which
  - Cuts off escaping exhaust gasses
  - Builds up back pressure in engine preventing it from increasing speed
- Are usually activated by a foot-operated switch
- They are
  - Quiet
  - Inexpensive
  - Reasonably maintenance free
- However they are
  - Prone to deterioration since they are always in the exhaust gas flow
- Not nearly as effective in terms of retardation as most other supplementary retarding systems
- EXAMPLES: Williams Air Controls - "Blue Ox"
  Mercedes Trucks - "Exhaust Brake"

Engine Brakes

- Probably most widely used type of retarder
- Is built into head of engine
  - Alters valve timing
  - Turns engine into an air compressor
- May be operated
  - Manually using a dash-mounted switch
  - Automatically - preselected to cut in when foot is taken off treadle valve
- They are
  - Very sophisticated
  - Fairly expensive
- Engine brakes will allow
  - Faster upshifts in transmission since engine is slowed when foot is taken off treadle valve
  - Very useful on steep grades
- EXAMPLES: Jacobs Manufacturing Company - Jake Brake
  Mack Truck - Dynatard

Hydraulic Retarders

- Are one type of drive line retarder
- Usually mounted between engine and flywheel
- Use oil directed against vanes in a stator to slow vehicle
- The more oil allowed to enter retarder the greater the retardation

- Hydraulic retarders
  - Are quiet
  - Require little maintenance
  - Eliminate shock to driveline components due to smooth engagement and disengagement
  - Are fairly expensive
  - May be activated manually or automatically
- EXAMPLES: Caterpillar Tractor Company - Cat Brakesaver
  - Detroit Diesel Allison - Allison's Integrated Retarder

Electric Retarders

- Another type of drive line retarder
- Contain electro-magnets
- Usually mounted on either the
  - Drive shaft
  - Rear end of transmission, or
  - Drive axle(s)
- Consists of
  - Magnets mounted directly to truck
  - Rotors which rotate with drive shaft
- When magnets are activated, usually by a switch in cab
  - Electrical system energizes magnets
  - Magnets exert a retarding force on rotors which slow the drive line
- Electric retarders
  - Have no parts to wear
  - Provide very effective and powerful braking capacity
- However, they are
  - Very costly
  - Much heavier than other types of retarders
- EXAMPLES: Jacobs Manufacturing Company - Jake ER Brake
  - Francoise Telma - Telma Retarder

Four Examples of Heavy Vehicle Retarders and How They Function

Williams Air Control Company's Blue Ox Exhaust Brake

- Description
  - The Blue Ox is basically a slide-action gate butterfly valve fitted into the exhaust pipeline between the
    - Exhaust manifold
    - Muffler
  - The Blue Ox
    - Restricts exhaust flow
    - Causes a build up of 30-60 psi of pressure in the exhaust manifold
    - Transforms engine into a low pressure air compressor which
      - Is driven by vehicle's wheels
      - Slows down and holds back vehicle
  - This type of exhaust brake may be used on any 4-stroke cycle diesel or gasoline engine

- Components
    - Air or vacuum control valve (switch)
        - Located in cab
        - Turns exhaust brake "on" or "off"
        - Regulates amount of pressure exerted by brake (optional)
        - May be equipped with an optional electric assist
    - Treadle valve control -- automatically applies exhaust brake when foot is taken off accelerator (when control valve switch is in on position)
    - Air pressure regulator -- regulates and controls air pressure to exhaust brake actuating cylinder
    - Actuating cylinder -- activates (opens and closes) butterfly valve
    - Butterfly valve
        - Traps exhaust gases causing braking action when closed
        - Allows vehicle to operate normally when open
- Operation
    - For the brake to operate the control valve in cab must be activated
    - There are two types
        - Standard switch
            - Has only two positions: "on" and "off"
            - Switch must be moved to "on" position to activate brake
        - Optional control switch
            - Has four control positions
                - Position 1
                    - Vehicle not in use
                    - Exhaust brake is off
                - Position 2
                    - For ice, snow or very slick surfaces
                    - Holdback pressure is reduced
                - Position 3
                    - For wet or slick streets
                    - Holdback pressure is increased
                - Position 4
                    - For dry pavement
                    - Brake is on all the way
    - After control switch has been turned on, every time treadle valve is released exhaust brake starts working
        - Air pressure regulator valve operates actuating cylinder
        - Cylinder closes butterfly valve
        - Butterfly valve
            - Traps exhaust gases
            - Creates retarding effect on engine
    - Stroke-by-stroke description of what happens when butterfly valve closes
        - Exhaust stroke
            - Exhaust valve opens
            - Exhaust brake restricts escape of exhaust gases from manifold

      - Each succeeding exhaust stroke builds up back pressure in manifold
      - Retards piston movement
      - Engine turning against back pressure plus normal friction creates retarding effect to wheels
    - Intake stroke
      - Intake valve opens
      - Exhaust valve is closed
      - Air is drawn in
    - Compression stroke
      - Both intake and exhaust valves closed
      - Air is compressed as normal
    - Power stroke
      - Since treadle valve is released
        - Little or no fuel is delivered to cylinders
        - Little or no torque is added to crankshaft
  - When treadle valve is depressed
    - Actuating cylinder opens butterfly valve
    - Exhaust gasses are allowed to escape
    - Engine operates normally

Jacobs Manufacturing Company's Jake Brake

- Description
  - The Jake Brake is a hydraulic engine attachment that "converts" engine to an air compressor
  - Is built into the head of the engine
  - The Jake Brake
    - Opens exhaust valves at or near top dead center of compression stroke
    - Causes compressed air to be blown down into exhaust manifold and eventually into atmosphere
    - Eliminates power stroke
  - Deprived of a power stroke, the engine obtains energy need to
    - Compress air in each cylinder
    - Overcome function
    - Do its other normal work (e.g., turning generators, fans, etc.)
  - By
    - Extracting energy from the vehicle's momentum, thus
    - Applying a retarding force to the drive wheels
  - This type of engine brake may be used on both two- and four-stroke cycle engines (e.g., Cummins, Detroit Diesel, In-line Macks, Cat 3406)
- Components
  - Control switches
    - There are three control switches wired in series:
      - Dash switch
        - Manually controlled by driver
        - May have three position setting, letting driver regulate amount of retardation
      - Clutch and treadle valve switch
        - Are activated when the driver depresses or removes feet from either of the pedals

    - All three switches must be closed in order to transfer power to engine brake housing
  - Solenoid valve
    - Is a three-way valve
    - Activates hydraulic system using an electrical signal
  - Control valve--provides engine oil at a regulated pressure to operate system hydraulically
  - Master piston
    - Picks up motion of injector rocker
    - Transfers its energy to the slave piston
  - Slave piston--opens exhaust valves at the top of compression stroke
- Operation
  - Dash switch must be in "on" position
  - Clutch and treadle valve switches must be closed (e.g., both control pedals must be released)
  - When this occurs
    - Solenoid valve is energized
    - Engine lube oil flows under pressure through control valve to both master and slave pistons
    - Oil pressure causes
      - Master piston to move down, thus
      - Resting on injector rocker clevis
    - In normal injector cycle
      - Injector rocker clevis moves upward
      - Clevis forces master piston also to move up
      - Creates high pressure oil flow to slave piston
      - Slave piston
        - Is forced downward
        - Opens exhaust valves releasing compressed air down into exhaust manifold
      - Compressed air escapes to atmosphere completing a braking cycle

Caterpillar Tractor Company's Cat Brake Saver

- Description
  - The Brake Saver retards engine by hydraulic action on the flywheel
  - It is mounted immediately ahead of engine flywheel
  - The Cat Brake Saver
    - Uses engine oil as the retarding force, eliminating the need for an additional oil system
    - Directs oil against stators attached to drive line
    - Churning action of oil converts energy into heat, slowing engine
  - The more oil volume present, the greater the retarding effect
  - This type of retarder may be used only on Caterpillar engines
- Components
  - Air-actuated control system
    - A control switch located on steering column has two settings
      - Manual only
      - Automatic-manual

        - Manual only
            - Can regulate amount of air pressure (through a hand lever) going to the Brake Saver, thus controlling volume of oil being directed toward stator, which determines amount of net retarding action
        - Automatic-Manual
            - May be operated manually by using hand lever or automatically by lifting foot off treadle valve which places Brake Saver into maximum retarding mode
    - Charging pump
        - Is actually the second half of a special two-section engine oil pump
        - Pumps oil from engine crankcase to oil control valve
    - Internal tubing
        - Transfers oil from crankcase to retarder
    - Rotor
        - Attached to crankcase
        - Directs oil against stator
    - Stator
        - Is a fan-like device
        - Engine oil from rotor is directed at stator
        - Stator contains vanes which rotate with drive line
        - Engine oil from rotor is directed at stator
        - Stator contains vanes which rotate with drive line
        - Engine oil slows rotating stator
    - Oil control valve
        - Controls flow of oil into Brake Saver
        - Air pressure regulated by control valve, sends oil to retarder
- Operation
    - Control switch must be placed either in the manual only or automatic-manual setting
    - When hand lever is activated or foot is taken off treadle valve
        - Engine oil is moved from the crankcase to the oil control valve by the charging pump
        - Air pressure regulated by the control switch, forces the oil into the rotor
        - Rotor attached to crankcase (whirling around) directs oil against rotating stator vanes
        - Oil against stator vanes, builds up pressure between rotor and stator, creating tremendous heat, thus slowing rotation of drive line which retards vehicle movement
    - When foot is taken off accelerator or control switch, hand lever is moved to "off" position
        - Oil control valve shuts off oil supply to the retarder
        - Rotor pumps remaining oil back to oil control valve
        - Control valve sends oil to oil cooler (friction build up between rotor and stator is very high, creating a need for an oil cooler to cool engine oil before it returns to crankcase)
        - Engine returns to normal operation

Detroit-Diesel Allison Integrated Retarder

- Description
  - The Allison Integrated Retarder
    - Is an integral part of transmission
    - Is located in the transmission in front of the gear range system
    - Permits maximum braking horsepower to be developed in each range
  - The Retarder
    - Uses transmission oil, forcing it under pressure into a cavity formed by the rotor and stator
    - Oil slows rotation of rotor, thus retarding vehicle movement
    - The more pressurized oil in the cavity, the greater the resistance to the vehicle's wheels, turning the higher the developed braking power level
  - The system
    - Is small, lightweight and powerful
    - Adds only four inches to length of transmission
    - Capable of absorbing over 400 braking horsepower
- Components
  - Control valve
    - Located in cab
    - Has varying settings so driver can dial in varying braking power levels
  - Rotor
    - Is the only moveable part in The Retarder
    - Resembles a vaned wheel
    - Is an integral part of transmission torque converter output shaft
    - Revolves with shaft
    - Is mechanically connected to wheels
  - Stator
    - Resembles a cavity with fixed vanes
    - Is cost into a housing which encloses rotor
    - Is stationary, does not revolve
- Operation
  - When control valve in cab is turned on
    - Transmission oil is pumped into cavity created by rotor and stator
    - Vanes on rotor now have to rotate in the transmission oil
    - Oil in cavity, under pressure and working against rotor vanes
      - Slows rotor
      - Provides braking power to rear wheels
  - When control valve is placed in "off" position
    - Cavity is emptied of oil
    - No braking occurs

As braking power forces develops in the preserver, the oil
  - Absorbs the heat generated
  - Is circulated through transmission heat exchanger and cooled
  - Is then dissipated through the radiator to the outside air

Cool air is then circulated back to transmission to repeat cycle

Summary

- EXHAUST RETARDERS - In exhaust retarders, the engine works against back pressure created by closing off the exhaust pipe. Retarding power can be up to 70 percent of the engine horsepower with the engine running at rated rpm.

- ENGINE RETARDERS - In engine retarders, the engine uses up energy during the compression stroke then the exhaust valves are opened at the top of the compression stroke, preventing any energy from being applied during the power stroke. Retarding power can be up to 100 percent of engine horsepower with the engine running at rated rpm.

- HYDRAULIC RETARDERS - In hydraulic retarders, the engine works against hydraulic fluid in a closed housing. Retarding power can be greater than engine horsepower and can be independent of engine rpm.

- ELECTRIC RETARDERS - In electric retarders, rotors connected to the drive train work against eddy currents set up by stators connected to the vehicle frame. Retarding power can be greater than engine horsepower, but may lose effectiveness quickly during continuous use.

Braking the Vehicle with A Retarder

Retarders are controlled by the driver

- All systems have a master "on-off" switch

- All systems incorporate interlock switches associated with the clutch, throttle, engine rpm shifter, or brake.

  -- The clutch switch turns off the retarder when the clutch is engaged.

  -- The throttle switch turns off the retarder when the throttle pedal is released to the idle position.

  -- The engine rpm switch turns off the retarder when the engine rpm drops below idle rpm.

  -- The shifter switch is used with automatic transmissions and turns off the retarder to prevent engine stall during the shift operations.

-- The brake switch turns the retarder on when the service brakes are applied.

Not all retarder systems use all of these interlock switches. Check the owners manual for the proper operation of the interlock switches used.

- Use retarders to slow down--not your service brakes.
- User retarders to maintain speed control down hills--not your service brakes.
- Ideally you need only use your service brake to come to a complete stop and for emergencies.

Local and Normal Highway Driving

For flat, dry road conditions, the retarder should be left on at all times. Since the retarder is a slow down device, it is very effective for town driving and short hauls.

Instead of using service brakes, use the retarder to slow down when

- preparing to exit onto an off ramp.
- approaching traffic lights.
- approaching stopped or slow traffic.

Use the service brakes only to bring the truck to a complete stop or for emergency stops.

Retarder Use at Low Speeds

- Using engine and exhaust retarders at low rpms may cause engine stalling. If retarder does not turn off automatically at low rpm, reduce retarder power or turn it OFF.
- When retarder is used with an automatic transmission, transmission fluid may overheat if engine rpm falls too low. To prevent overheating, reduce retarder power to turn retarder OFF.

Going Down Hill

Before beginning descent, select the gear that lets you go downhill at a constant, controlled speed with little or no use of service brakes. Use the retarder to provide braking power.

The amount of downshifting needed depends on the type of retarder you have.

In General:

- ENGINE retarders

  go down hill in same gear as used to climb that hill.

- EXHAUST retarders

  go down hill in one gear lower than used to climb that hill.

- ELECTRIC retarders

  go down hill in gear higher than used to climb hill.

- HYDRAULIC retarders

  go down hill in the same gear used to climb that hill.

- Use service brakes oly when either the engine RPM or the vehicle road speed gets above safe limits.

Ice, Snow, Rain

Using a retarder when roads are wet or slippery may cause overbraking of the wheels. This may cause you to skid or jackknife. This is most apt to happen when your rig is empty or lightly loaded.

- Turn retarder off on icy or snow covered roads.
- Turn retarder off in heavy rain or when approaching wet bridge-decks or exit ramps.
- Reduce Retarder Power in light rain or on wet roads. If you cannot reduce retarder power, Turn Retarder Off.

Caution: Using a retarder on slippery roads could actually increase your stopping distance and/or cause a jackknife situation.

Curves

Retarders can be used on hills when the curves are properly banked and the pavement is not slippery. Be sure to

- Turn Retarder Off before you enter a flat and/or slippery curve.
- Turn Retarder Off before entering a curved exist ramp and the road is slippery.

Bobtailing or Towing Unloaded Trailers

It is recommended that you DO NOT use the retarder when bobtailing or pulling an empty trailer on slippery or wet pavement.

Remember: With retarder in operation drive wheel lock up can occur much more quickly than when using service brakes.

- Selecting proper transmission gear is very important
  - Retarders are more effective in the lower gears and at higher engine speeds
  - However, at no time should engine be allowed to exceed governed speed
- Remember
  - Transmission gear ratios control road speed
  - Service brakes control engine speed
- Control speed is obtained by
  - Activating control switch
  - Shifting into proper gear
  - Releasing clutch and/or accelerator
- Gearing the vehicle down within limits of rated engine speed
  - Makes retarders more effective, therefore,
  - Maximum retarding occurs with selection of lowest gear that does not exceed rated engine speed
- If maximum retarding is not needed and faster grade descent is desired
  - Select higher gear
  - Use steady pressure on service brakes to prevent engine from over speeding
- Using retarder on ice, snow or slick roads
  - Select higher than normal gear for given road speed without lugging engine
  - Engine will then operate at a reduced rpm level resulting in reduced retarding effect
  - On vehicles equipped with a progressive (variable) control switch, reduced retarding can be selected

Locating and Recognizing Problems

Inspection

- Walk around the vehicle
  - Look for air hoses that are worn, chaffed, cut or cracked
  - Look and listen for connections that are leaking or restricted, crimped or broken
  - Look for lines that are not properly attached or supported to prevent damage by vibration or abrasion by contact with the frame, axle or other moving parts of the vehicle
  - Look for any broken missing parts or locations with a clearly audible air leak
  - Check all slack adjusters to determine that they are all taken up in even amounts
    - Uneven adjustment of slack adjusters will result in uneven braking
      - The vehicle may pull to one side or the other
      - One axle may be doing more braking than the other

- It is essential that all brakes be evenly adjusted
  - This can only be controlled through even take-up of the slack adjusters throughout the vehicle. (Proper adjustment of slack adjusters will be discussed in Unit 4.2

- Check the air compressor and compressor reservoirs to make sure that they are securely attached
  - Any looseness is immediate cause for rejection of the vehicle for safety
- On belt drive compressors, make sure that belts are not defective and that pulleys are in good condition
- Disconnect the air lines to the trailer
- The air loss should stop almost immediately
  - The trailer relay emergency valve should go on applying the trailer brakes and the trailer brakes should remain applied for at least 5 minutes
- The following test should be made by the driver to determine if the system is functioning properly:
  - Test #1
    - Drain both the wet and dry air tanks to zero
    - Close petcock
    - Start engine, run at fast idle
    - When pressure reaches 50 psi, start timing
      - Note the low pressure warning cutoff
      - If it is below 50 psi or above 70 psi, it is in need of correction
    - Continue timing
      - If pressure mounts from 50 psi to 90 psi within 3 minutes, build-up is OK
      - If the build-up takes longer, the pressure build-up time needs improvement
    - Continue pressure build-up until governor cuts out
      - If below 100 psi or above 125 psi cutout, it is in need of adjustment
    - Have adjustments made before attempting to operate
  - Test #2
    - With full pressure engine shut off and brakes released:
    - Allow maximum system pressure to stablize for at least 1 minute
    - Observe pressure gauge and begin timing for 2 minutes
    - Pressure drop should not be more than
      - 2 psi in 1 minute for the tractor only
      - 3 psi in 1 minute for a tractor-trailer combination
      - 3 psi in one minute for a double-bottom combination
    - Drops in pressure greater than those listed above indicate malfunctions which must be corrected before attempting operation
  - Test #3
    - With full pressure built up and engine shut off
    - Apply treadle brake valve and allow pressure to stablize for at least 1 minute
    - Continue to apply foot brake, observe gauge and time for 2 minutes

- Pressure drop should not be more than
    - 3 psi per minute for tractor only
    - 4 psi per minute for a tractor-trailer combination
    - 6 psi per minute for a double-bottom combination
- Drops in pressure greater than those listed above indicate malfunctioning which must be corrected before attempting operation

Test #4

- With pressure at least 90 lbs., and engine shutoff
- Make foot brake applications repeatedly until low air pressure indicator comes on
    - If it comes on above 70 psi or below 50 psi, it is in need of correction and must be fixed before attempting to operate
    - It should be noted that this low pressure indicator should come on before the trailer brakes apply
- Continue fanning off the air pressure by reapplying the foot brake until the trailer brakes apply automatically
    - If they apply above 45 psi or below 20 psi, the system is malfunctioning
    - Have it fixed before attempting to operate

Test #5

- Manual Emergency System Test--With full pressure built up in the system and engine running at a fast idle (600 to 900 rpms)
- Operate the manual emergency controls
- Check for sluggish application or sluggish release
    - Either indicates need for correction
- With control valve lever or button at "normal" disconnect the emergency line to the trailer
    - If the trailer brakes do not apply fully and immediately the relay emergency valve should be considered defective
    - Repair it immediately before attempting to operate the vehicle

Servicing

- Drivers must be sure to drain air reservoir tanks
    - At least daily in cold weather
    - At least every other day during other periods of time
    - This is necessary to prevent moisture build up in the lines that can cause deterioration of the system and/or freezing of the valves
    - Care must be taken in draining air reservoirs to make sure vehicle is properly chocked and blocked against any movement

Operation

- During operation, drivers must continually monitor instrument panel to determine sufficiency of pressure in air system reservoirs
- At first indication of trouble, stop and locate the problem
- Do not gamble by driving with a malfunctioning system
- During operation, note
    - Any pulling to the right or to the left
    - Any sluggishness in the application or release of the brakes

READEX FICHE

    - Any indication that tractor brakes are going on before trailer brakes
- Check all slack adjusters to determine that they are all taken up in even amount
    - Uneven adjustment of slack adjusters will result in uneven braking
        - The vehicle may pull to one side or the other
        - One axle may be doing more braking than the other
    - It is essential that all brakes be evenly adjusted
    - This can only be controlled through even take-up of the slack adjusters throughout the vehicle (Proper adjustment of slack adjusters will be discussed in Unit 4.2)

- Be extremely cautious of making a hard brake application when pulling off the road and then immediately setting the paring brake
    - If the brake drums are extremely hot and the brake shoes are applied against the drums, warping of the drums can occur
- On cold, wet nights, when running through snow or slush, be extremely cautious of pulling into a truck stop or parking space and immediately applying the parking brakes
    - Shoes can immediately freeze to the drums making it impossible to move the vehicle--drag the brakes to dry them out
    - When in doubt
        - Do not apply brakes
        - Instead, chock the wheels and leave the transmission(s) in lowest combination forward gear(s)
- If the vehicle is equipped with an alcohol evaporator unit, make sure the reservoir is kept full of alcohol to assist in eliminating moisture/freezing related type problem
- When coupling, it is essential that all of the checks called for in Pre-Trip Inspection and in the Coupling and Uncoupling procedure be performed every time, carefully and fully
- Never assume that, because you have pulled this trailer before, that brakes are still okay--they may not be

Post-Trip

- Drivers must report promptly any indication of improper functioning of the brake system of either the tractor or trailers they may be pulling
- When leaving a trailer at a location, be sure to notify supervision immediately if there is something wrong with that trailer so that another driver does not pull it before repairs can be made

Recap

- Modern air brake systems are very complex devices
- It is essential that all drivers fully understand how each type functions in order to adequately check them before operation
    - The only thing more dangerous than operating a combination vehicle with a defective air brake system is operating that vehicle and not knowing that it is defective
    - Ignorance of how the systems work is no excuse any may result in a serious accident involving the death of the driver and/or others

- All drivers must be constantly on the alert for
  - Any sign of a new type of system or parts of a system with which they are not familiar
  - If confronted with something unfamiliar they should immediately have it explained by someone who is expert on it

  - Any sign of system malfunction during pre-trip and post-trip inspections.
  - Any indication while operating the vehicle that there is anything wrong with the air brake system
  - At the first suspicion that there is, immediately pull off the road
  - Determine if there is a malfunction and its cause
- All drivers have a moral, financial, and legal responsibility to
  - Thoroughly understand how the air brake system in their vehicle works
  - Know how to inspect it for any signs of malfunctions
  - Inspect it both pretrip and post-trip as required by both law and good safety practice
  - Refrain from operating such vehicle when and if there is any indication of malfunction
  - Take steps to ensure that someone else will not operate a vehicle while ignorant of the fact that there is a malfunction present

The above information on air brake systems also applies to retarders and auxiliary brakes

Levers Used in Braking

Figure 1

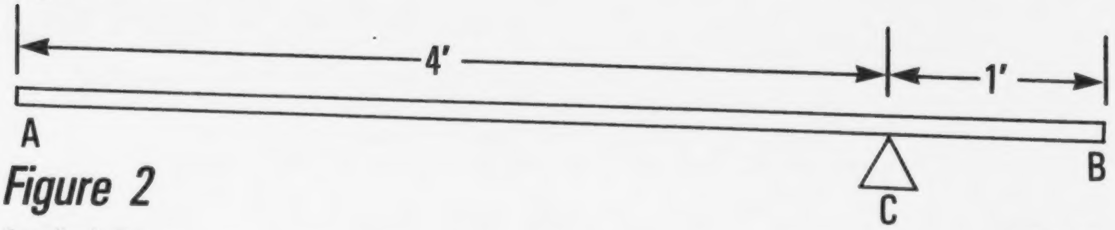


Figure 2

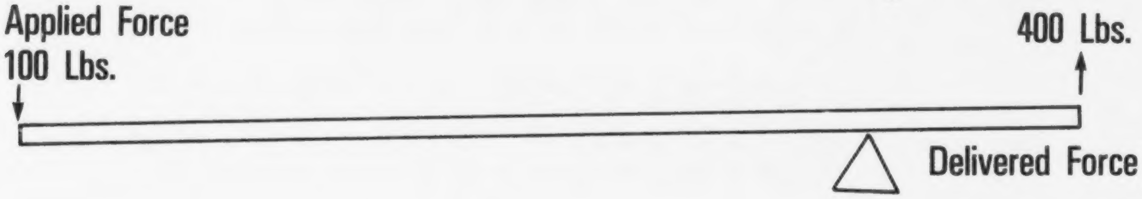
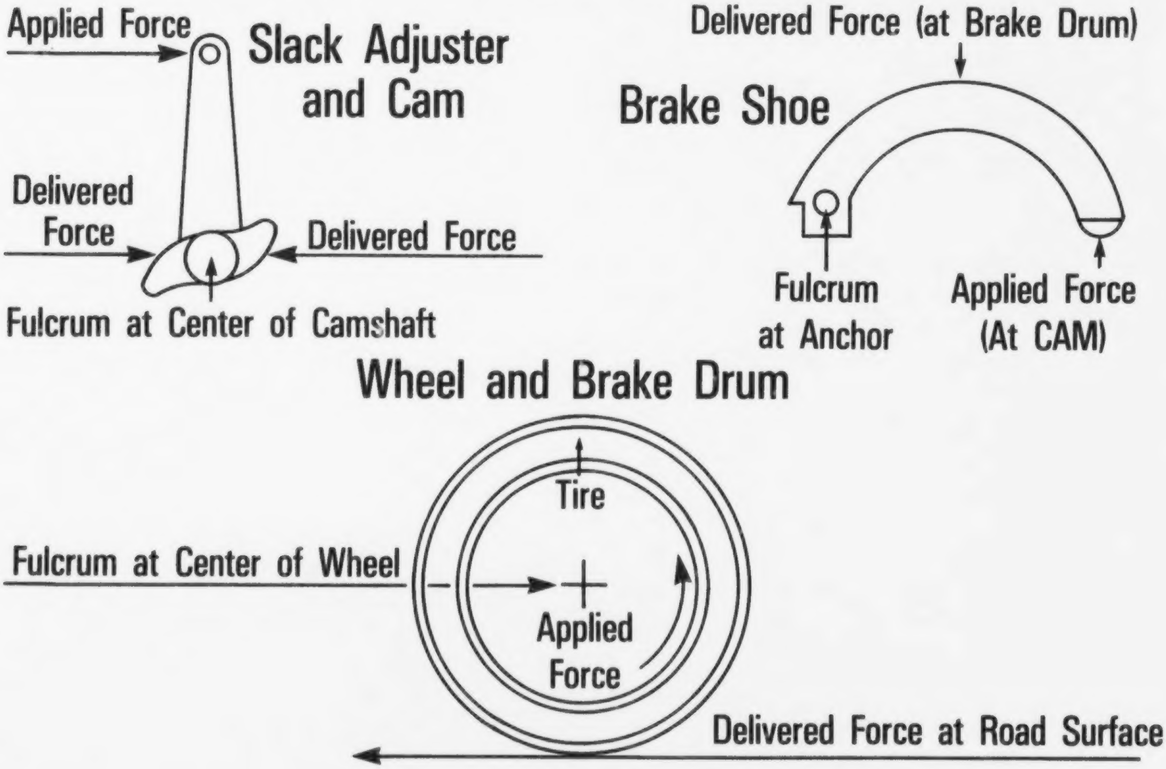
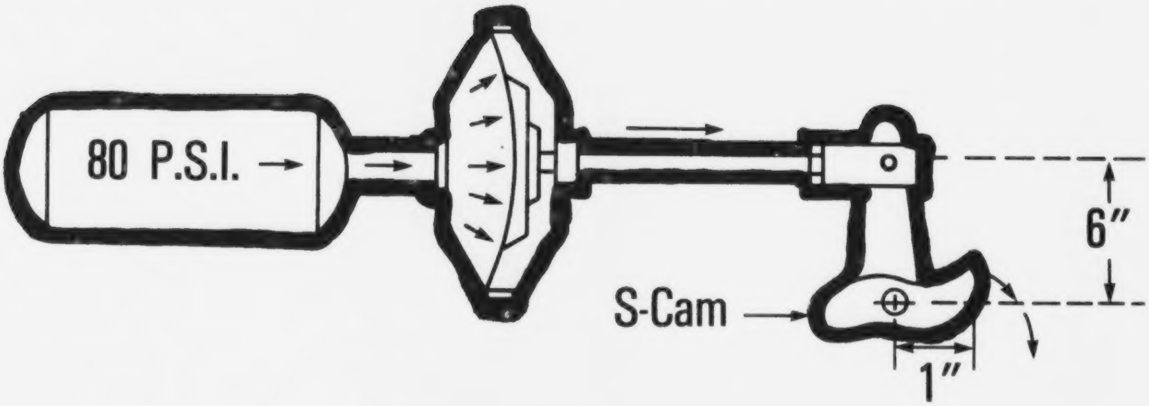

Applied Force
100 Lbs.
400 Lbs.
Delivered Force

Figure 3 Examples of Levers in Brake System


Applied Force
Slack Adjuster and Cam
Delivered Force
Delivered Force
Fulcrum at Center of Camshaft
Delivered Force (at Brake Drum)
Brake Shoe
Fulcrum at Anchor
Applied Force (At CAM)
Wheel and Brake Drum
Tire
Fulcrum at Center of Wheel
Applied Force
Delivered Force at Road Surface

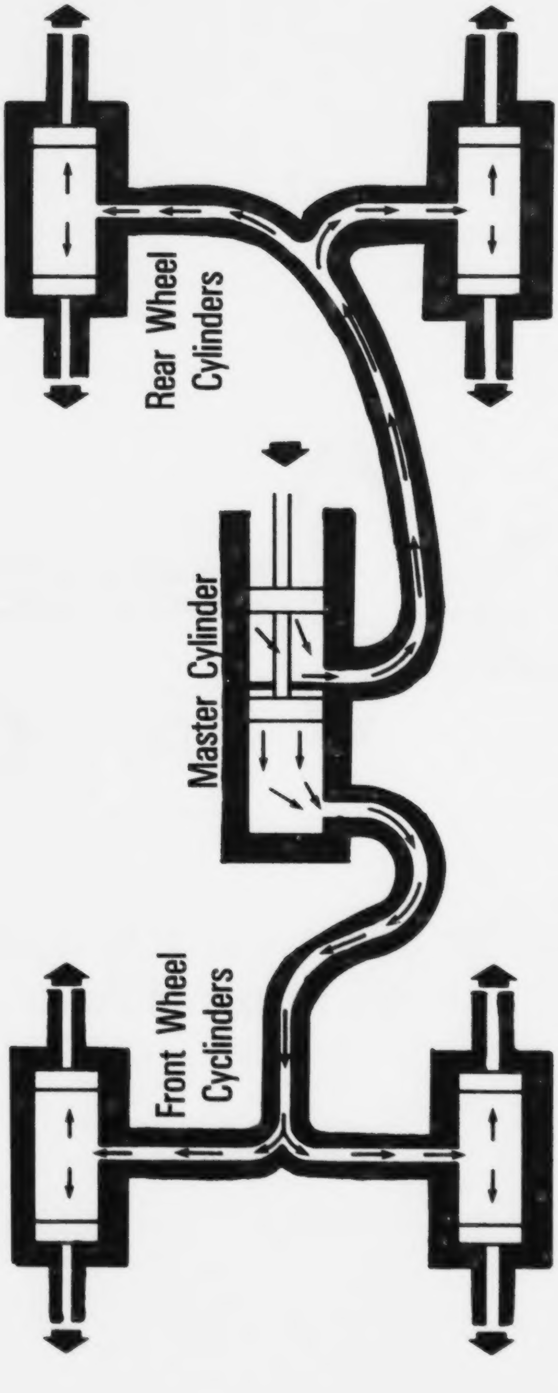
Visual 9.2

Air As a Force Multiplier

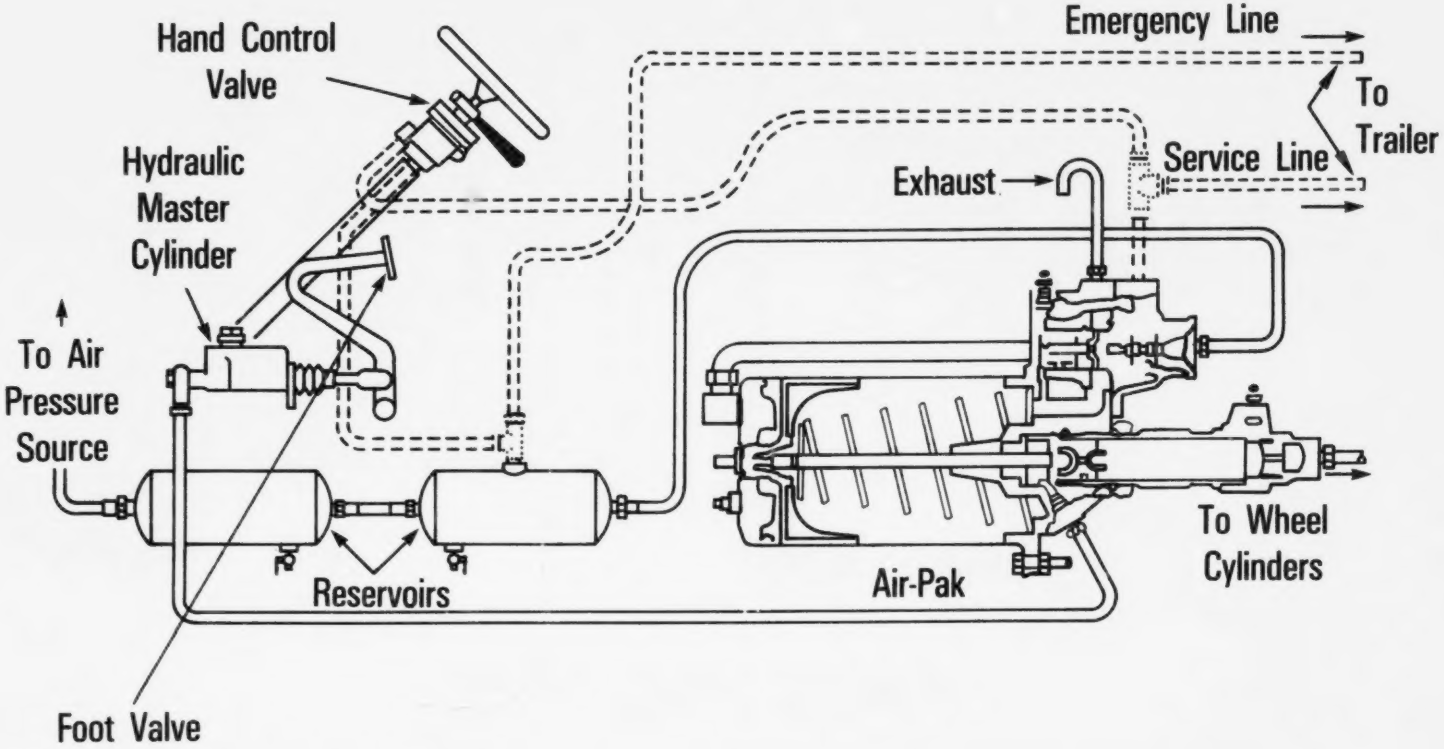

80 P.S.I.
6"
S-Cam
1"

80 Pounds Per Square Inch x 10 Square Inches =
800 Pounds of Force

Straight Hydraulic System

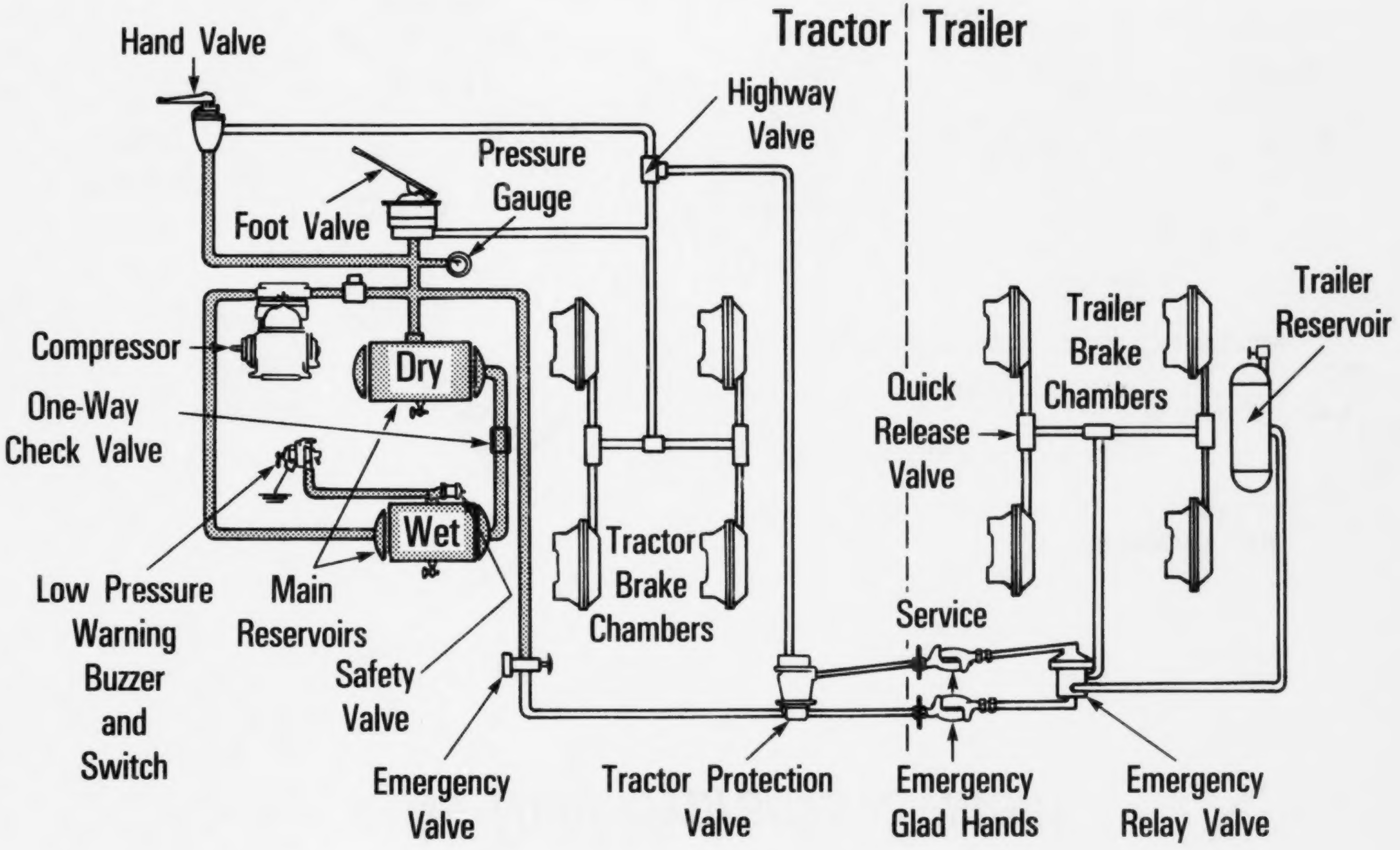

Rear Wheel
Cylinders
Master Cylinder
Front Wheel
Cyclinders

Air-Over-Hydraulic System


Hand Control Valve
Hydraulic Master Cylinder
To Air Pressure Source
Foot Valve
Reservoirs
Emergency Line
To Trailer
Service Line
Exhaust
Air-Pak
To Wheel Cylinders

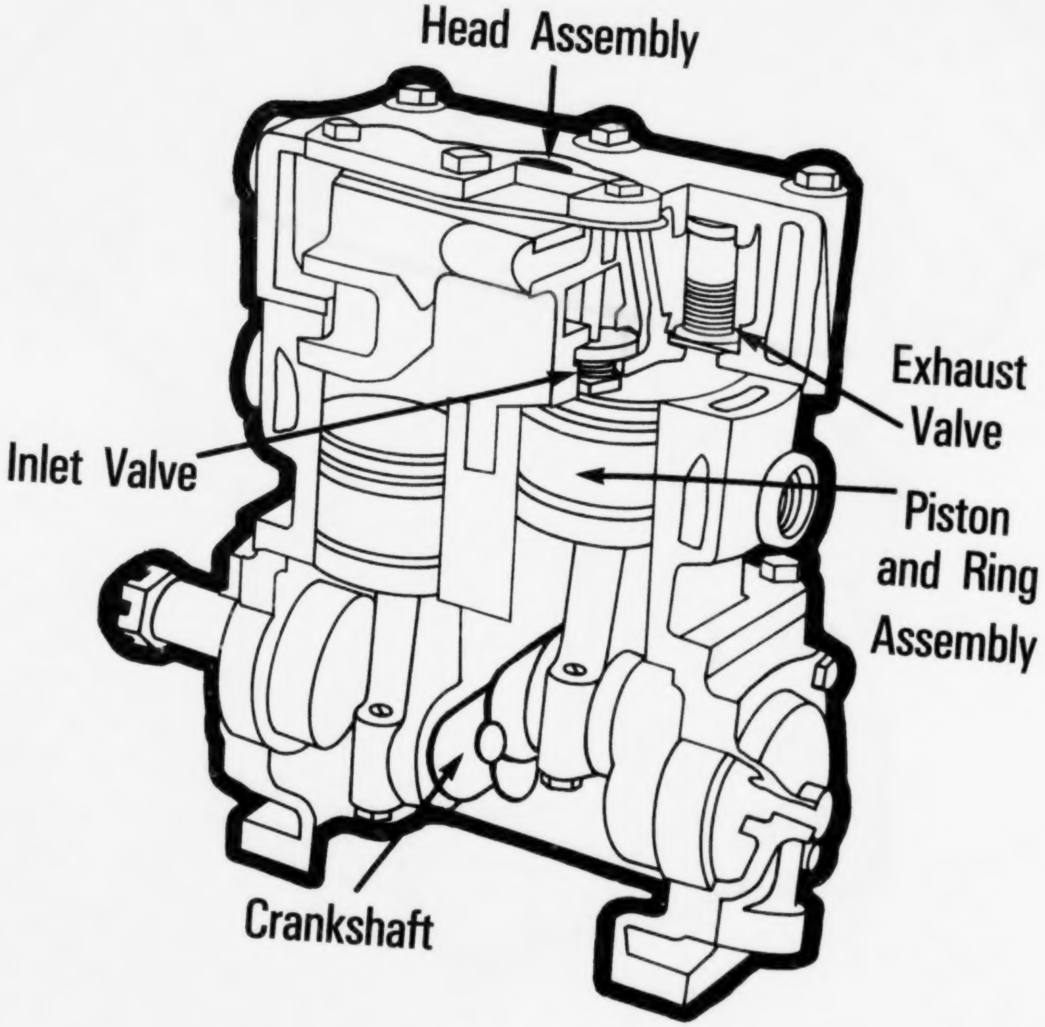
Air Brake System Components and Location

(Single Circuit System)

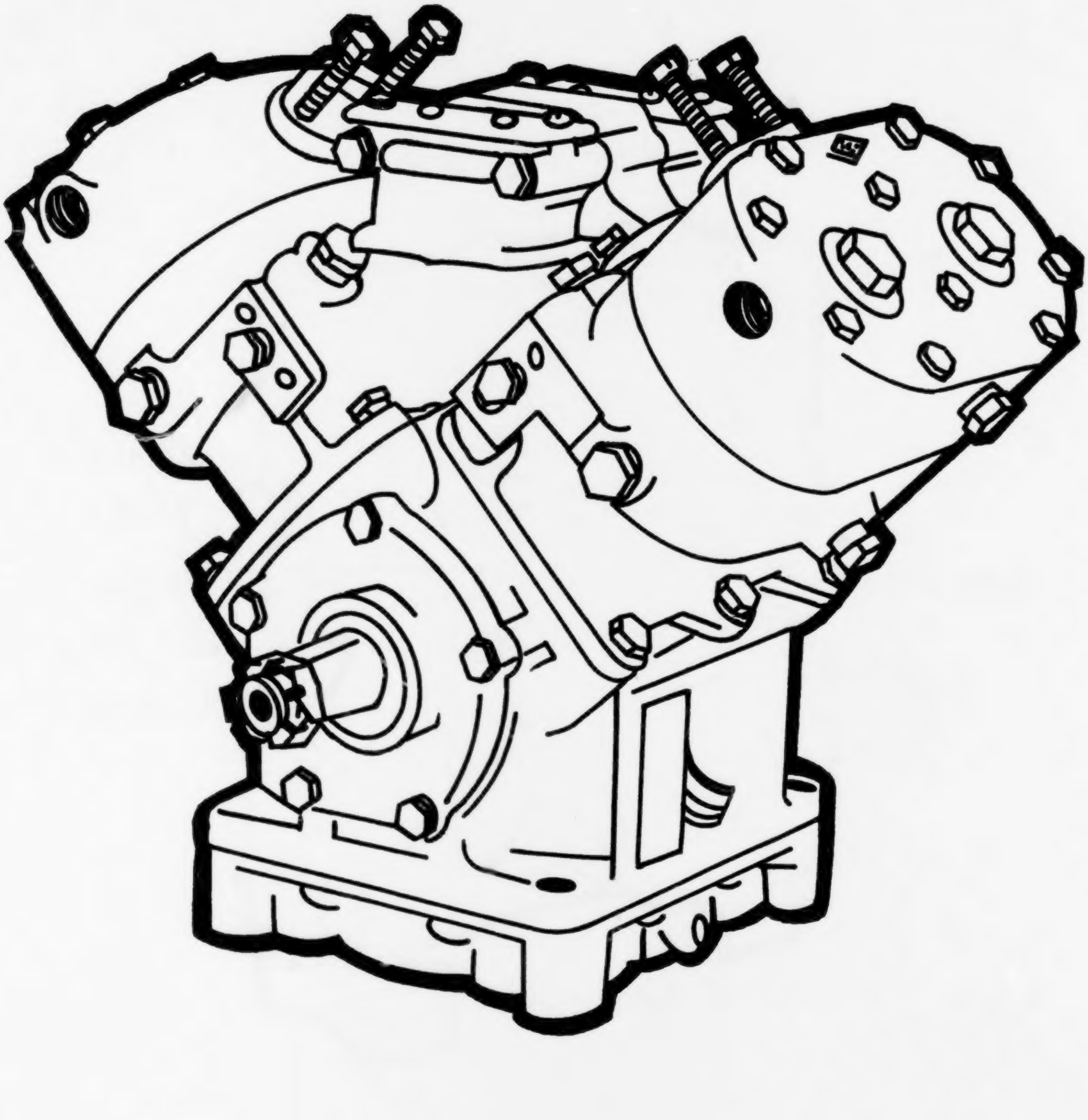

Tractor
Trailer
Hand Valve
Highway Valve
Pressure Gauge
Foot Valve
Compressor
Dry
One-Way Check Valve
Wet
Low Pressure Warning Buzzer and Switch
Main Reservoirs
Safety Valve
Emergency Valve
Tractor Brake Chambers
Tractor Protection Valve
Service
Emergency Glad Hands
Quick Release Valve
Trailer Brake Chambers
Trailer Reservoir
Emergency Relay Valve

Visual 9.6

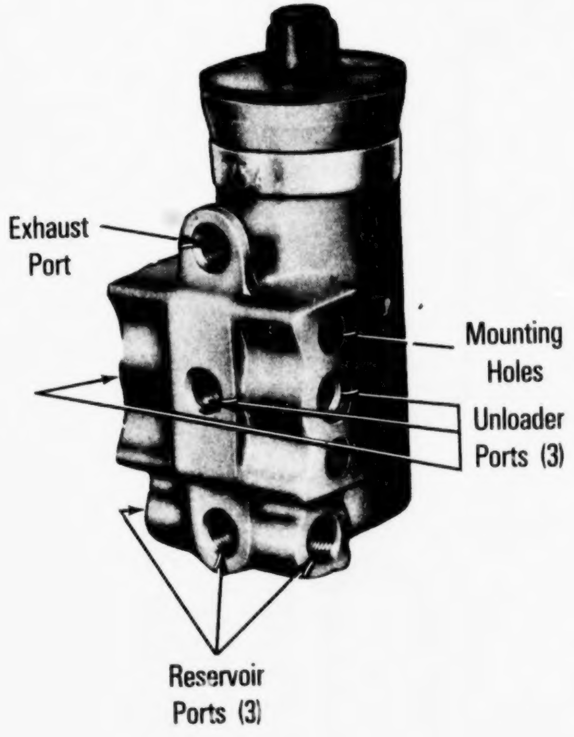
Reciprocating In-Line Air Compressor (Two Cylinder)

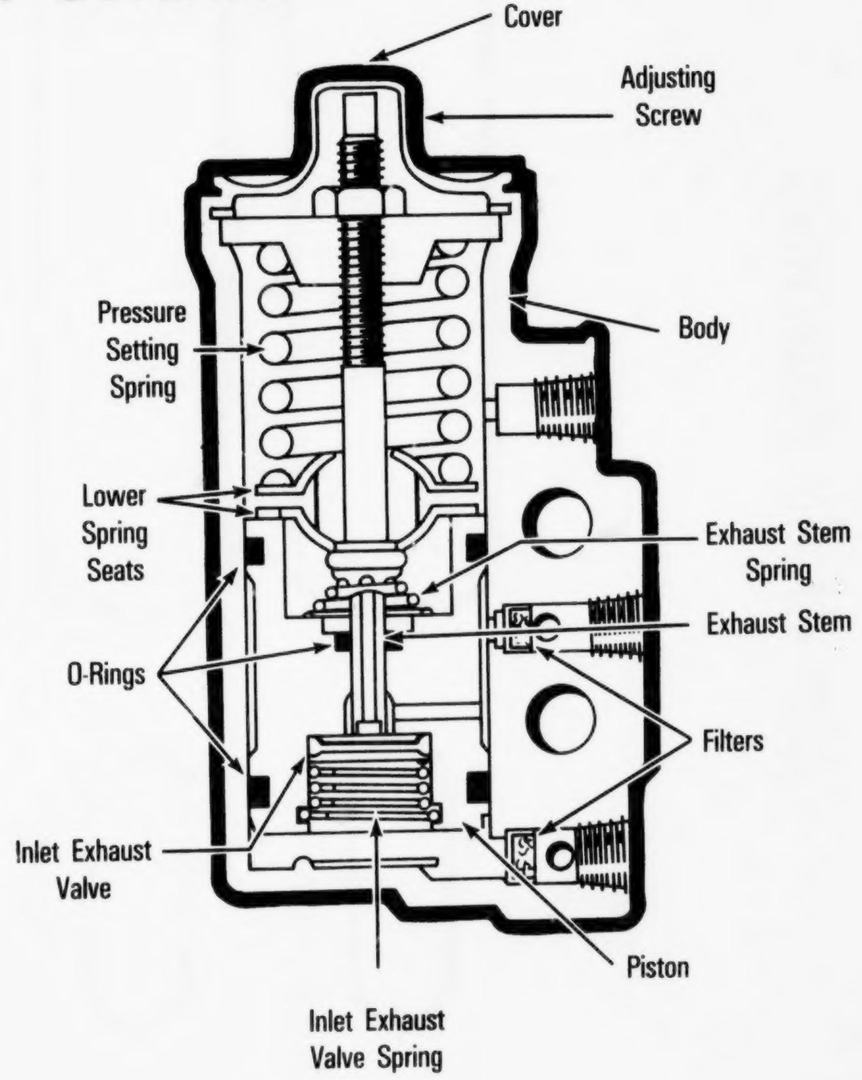

Head Assembly
Exhaust Valve
Inlet Valve
Piston and Ring Assembly
Crankshaft

Reciprocating Vee Air Compressor (Four Cylinder)



Air Governor

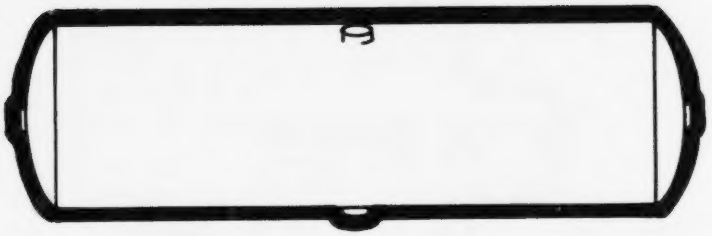

Exhaust Port
Mounting Holes
Unloader Ports (3)
Reservoir Ports (3)

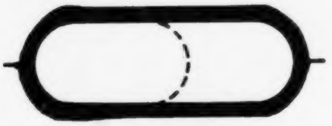

Cover
Adjusting Screw
Body
Pressure Setting Spring
Lower Spring Seats
Exhaust Stem Spring
Exhaust Stem
O-Rings
Filters
Inlet Exhaust Valve
Piston
Inlet Exhaust Valve Spring

Visual 9.9

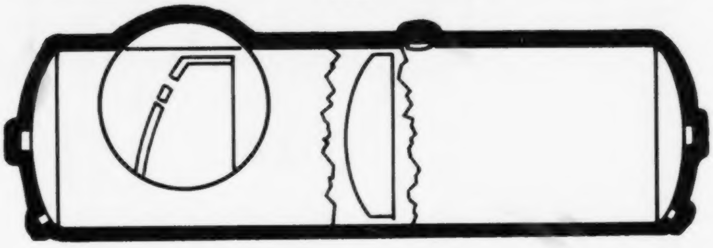
Types of Air Reservoirs

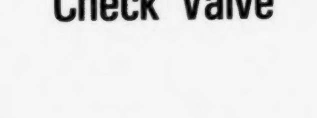
Single Compartment



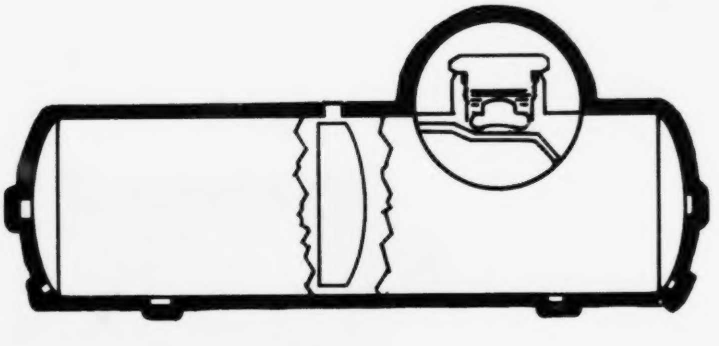


Baffled

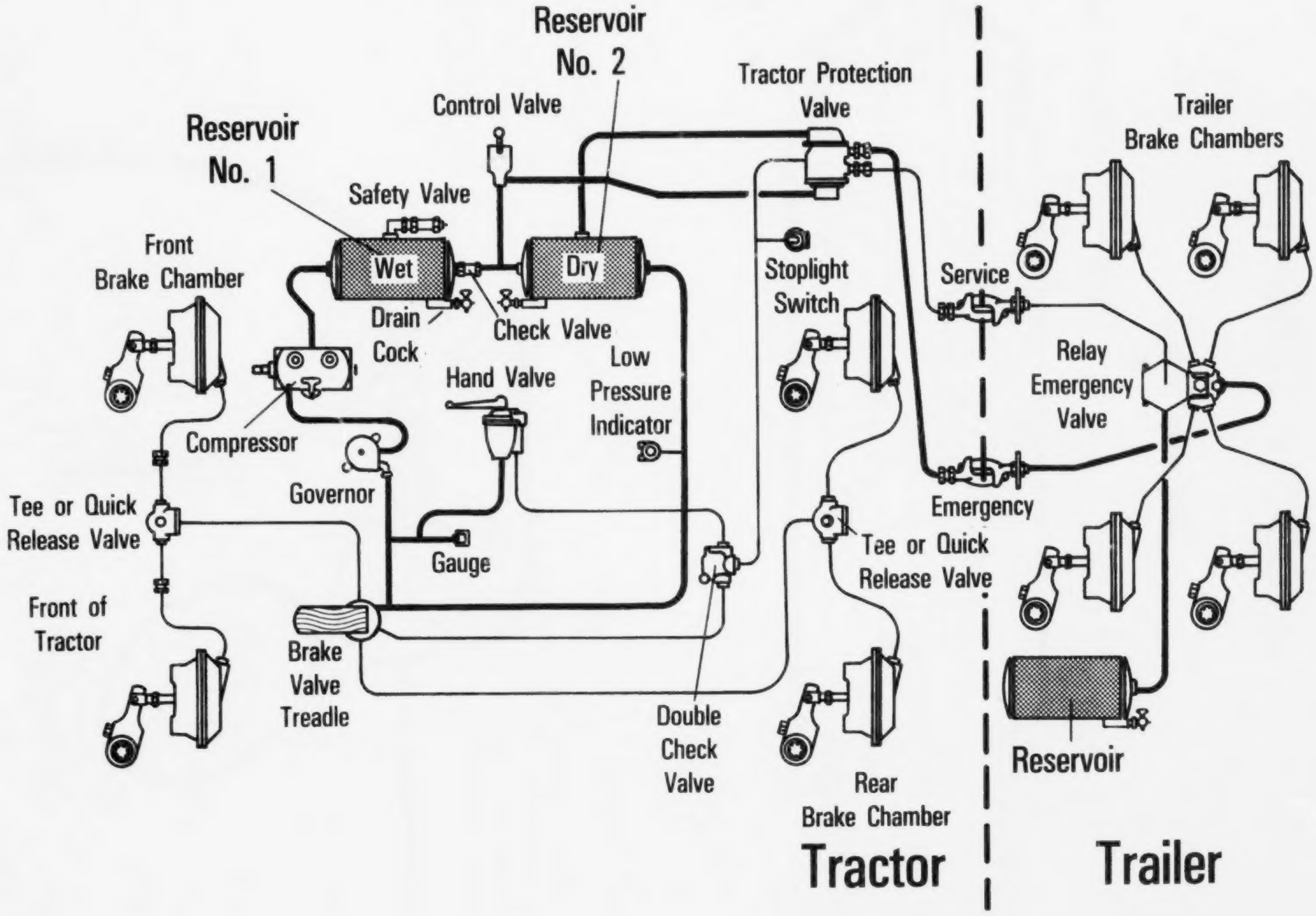




Multi Compartment With Integral Check Valve



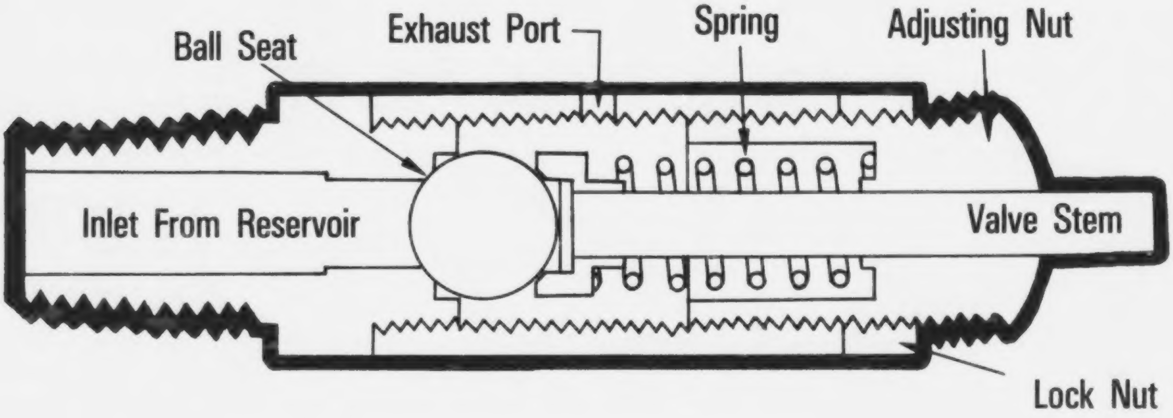
Location of Reservoirs

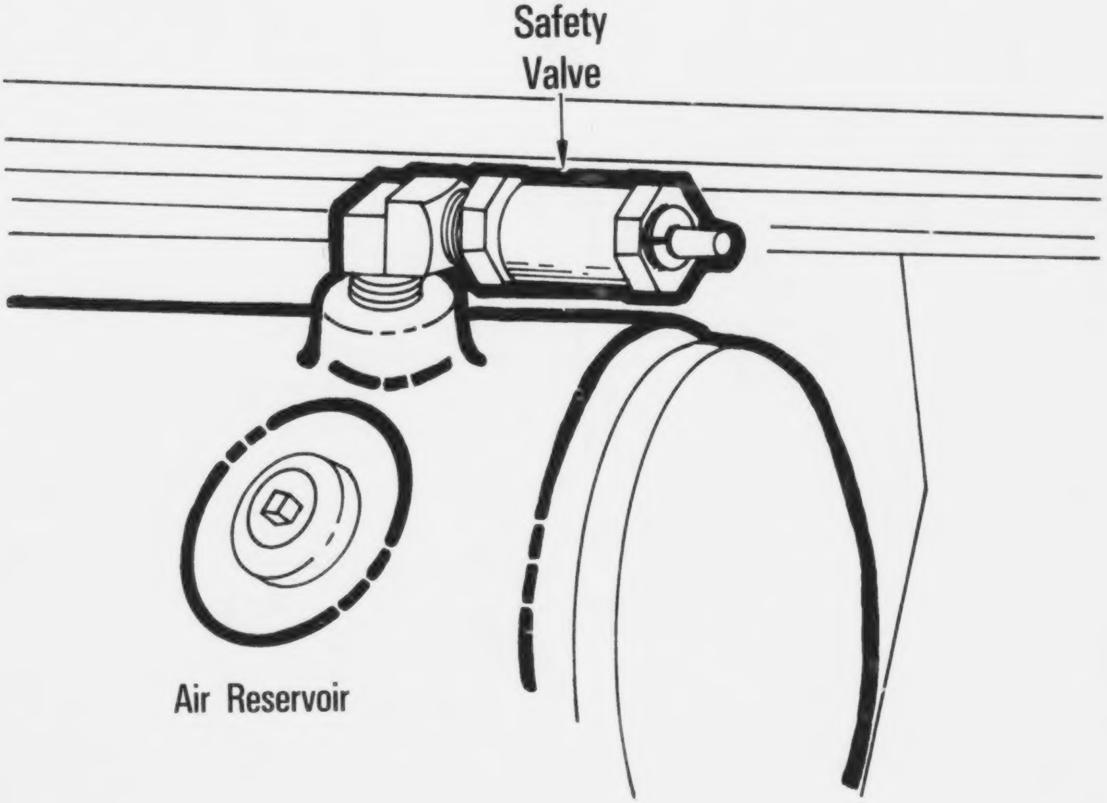

Reservoir No. 2
Tractor Protection Valve
Control Valve
Reservoir No. 1
Trailer Brake Chambers
Safety Valve
Front Brake Chamber
Wet
Dry
Stoplight Switch
Service
Drain Cock
Check Valve
Low Pressure Indicator
Relay Emergency Valve
Hand Valve
Compressor
Governor
Emergency
Tee or Quick Release Valve
Gauge
Tee or Quick Release Valve
Front of Tractor
Brake Valve Treadle
Double Check Valve
Rear Brake Chamber
Reservoir
Tractor
Trailer

Visual 9.11

Safety Valve

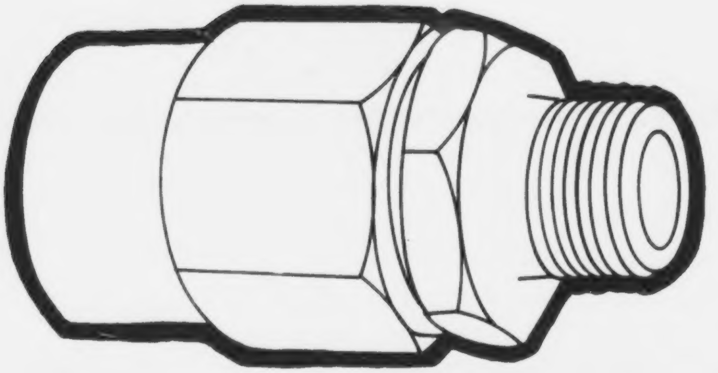
Cutaway View


Ball Seat
Exhaust Port
Spring
Adjusting Nut
Inlet From Reservoir
Valve Stem
Lock Nut

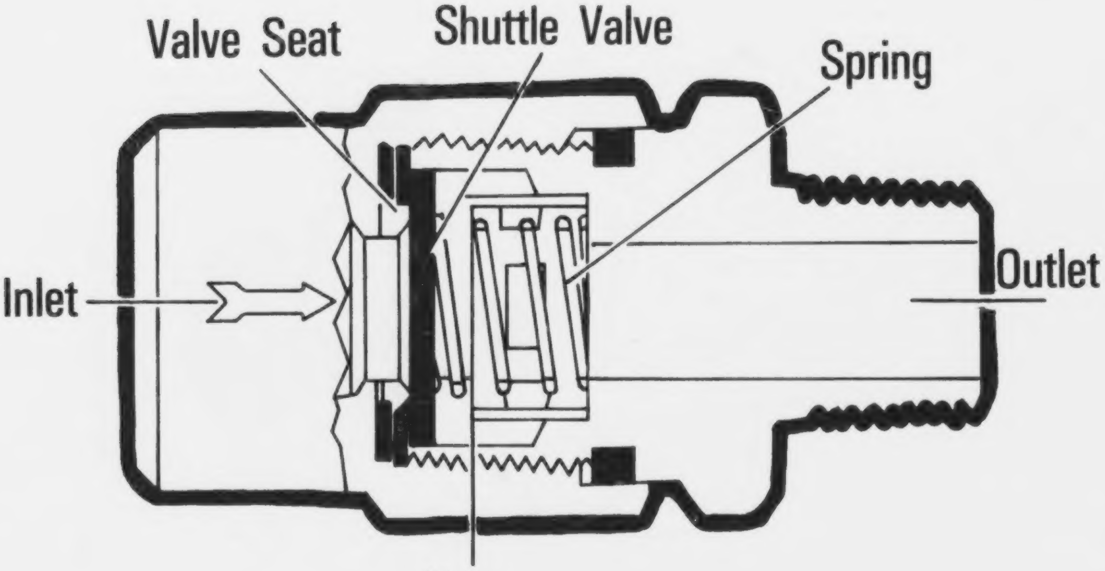

Safety
Valve
Air Reservoir

Visual 9.12

One-Way Check Valve

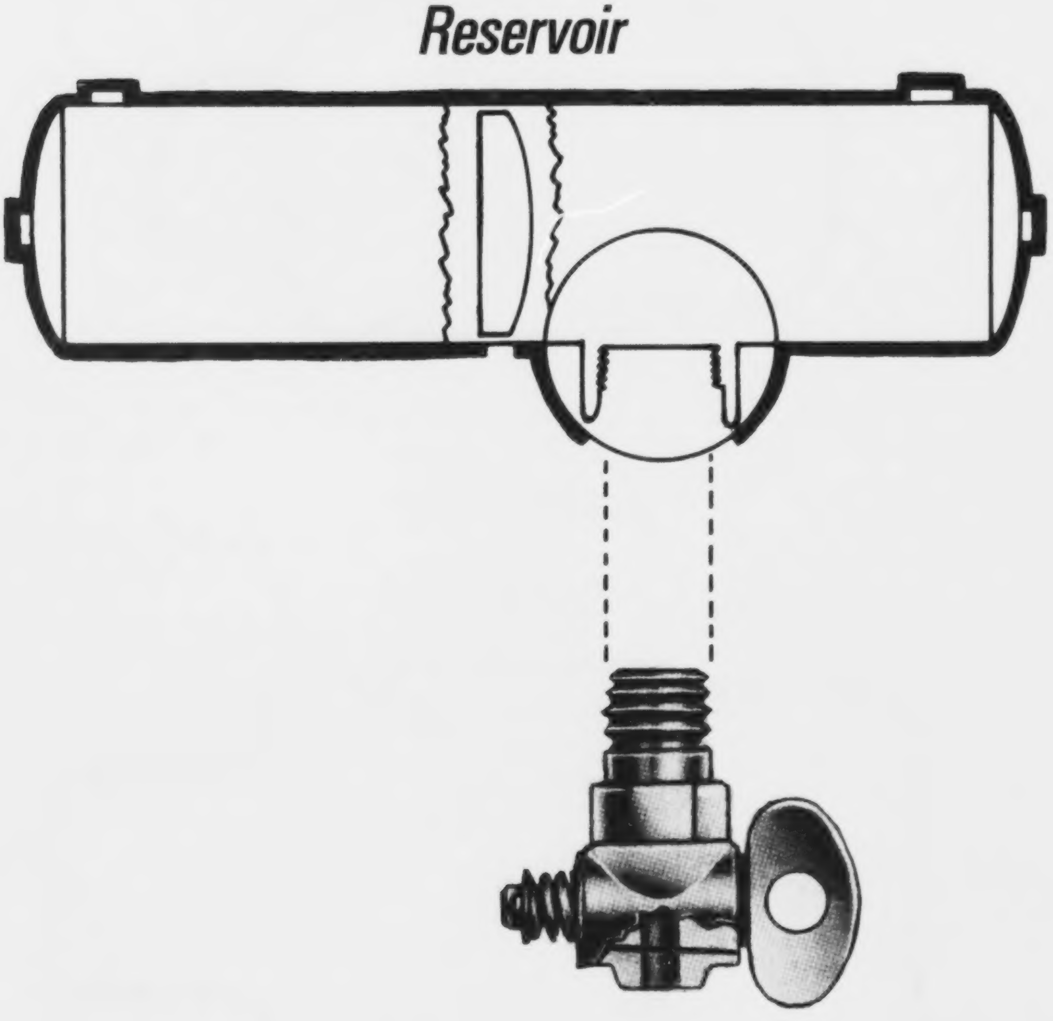


Cutaway View


Valve Seat
Shuttle Valve
Spring
Inlet
Outlet
Valve Stop

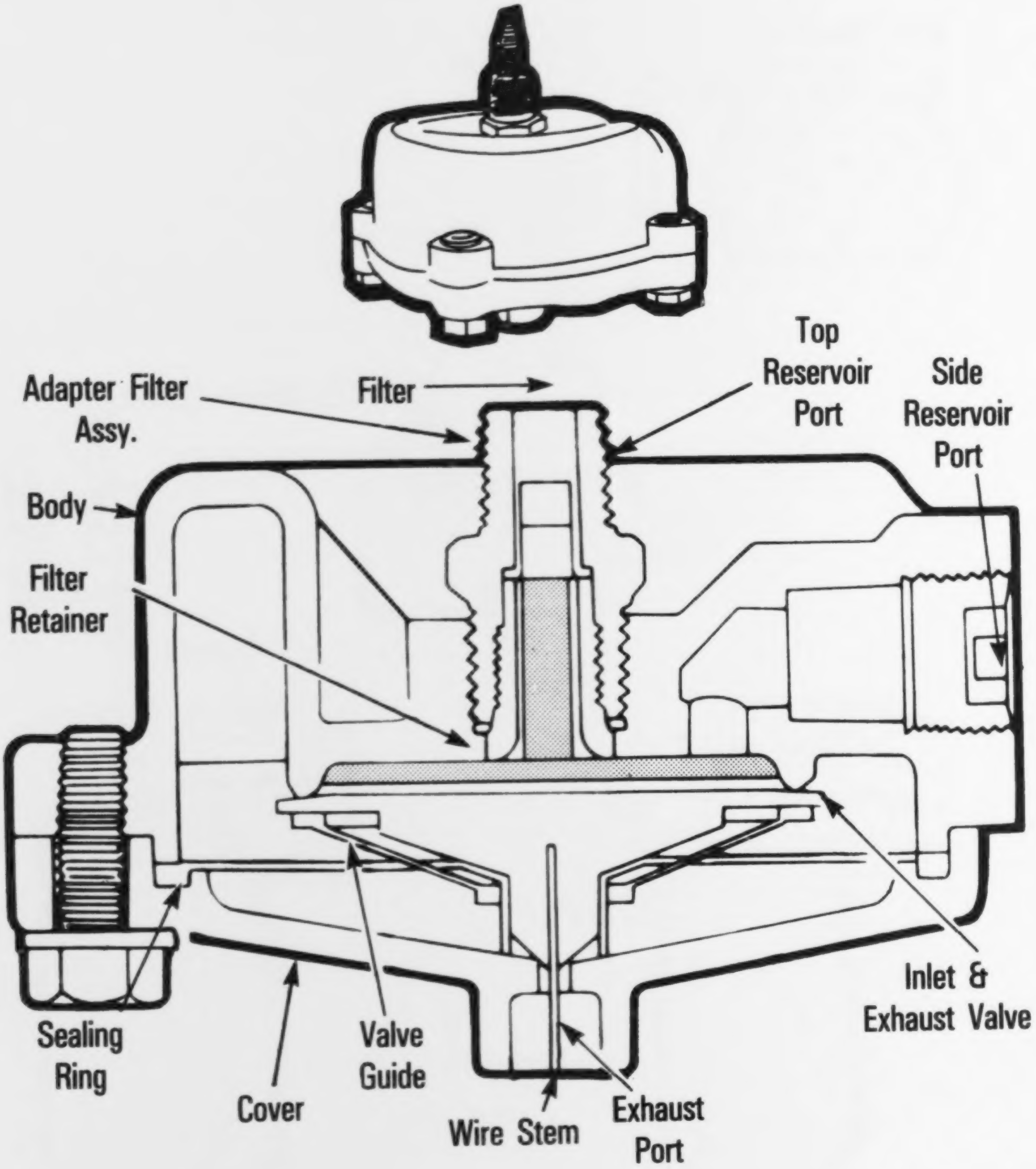
Visual 9.13

Manual Reservoir Draining Valve



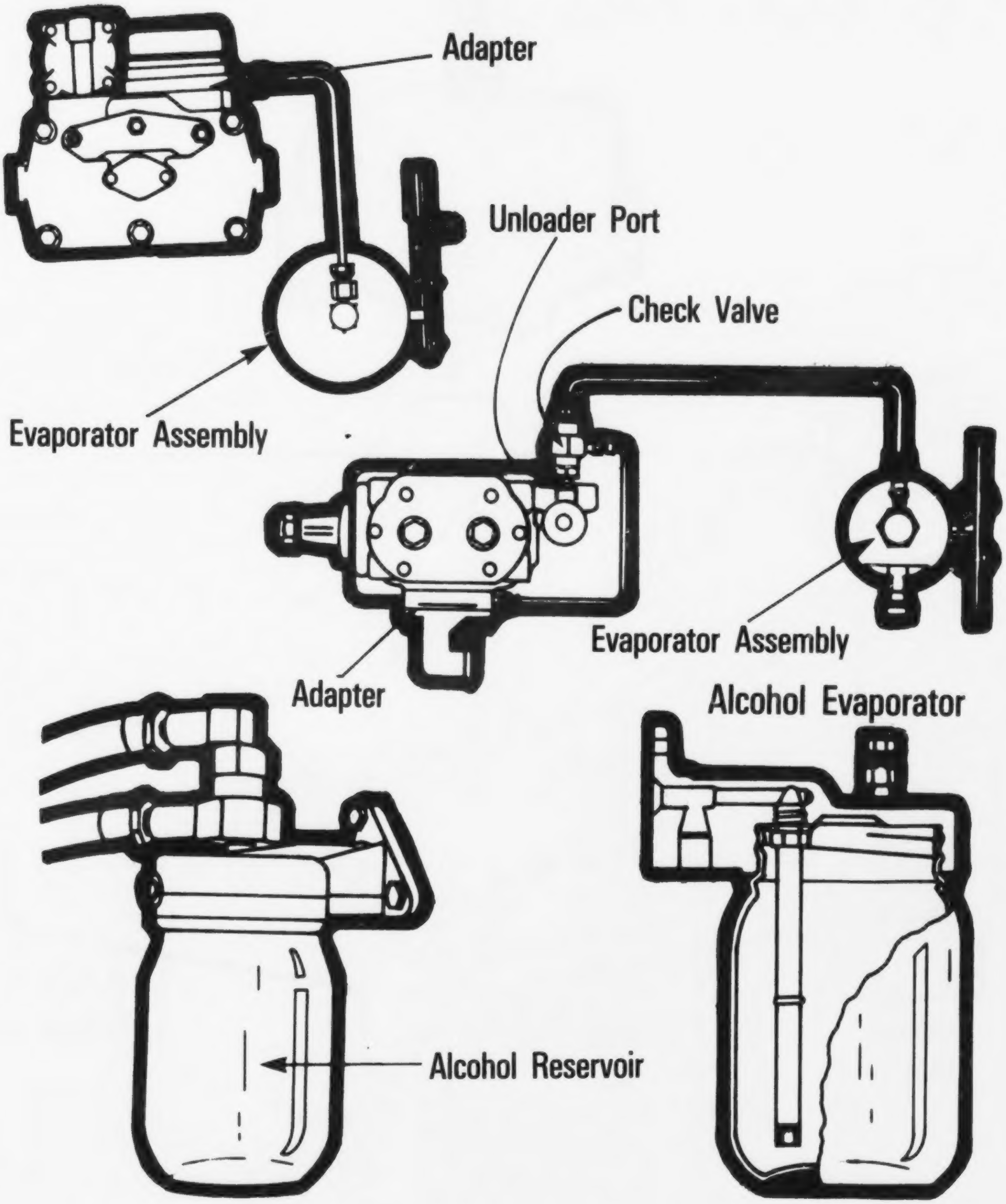
Visual 9.14

Automatic Moisture Ejector


Top Reservoir Port
Adapter Filter Assy.
Filter
Side Reservoir Port
Body
Filter Retainer
Inlet & Exhaust Valve
Sealing Ring
Valve Guide
Cover
Wire Stem
Exhaust Port

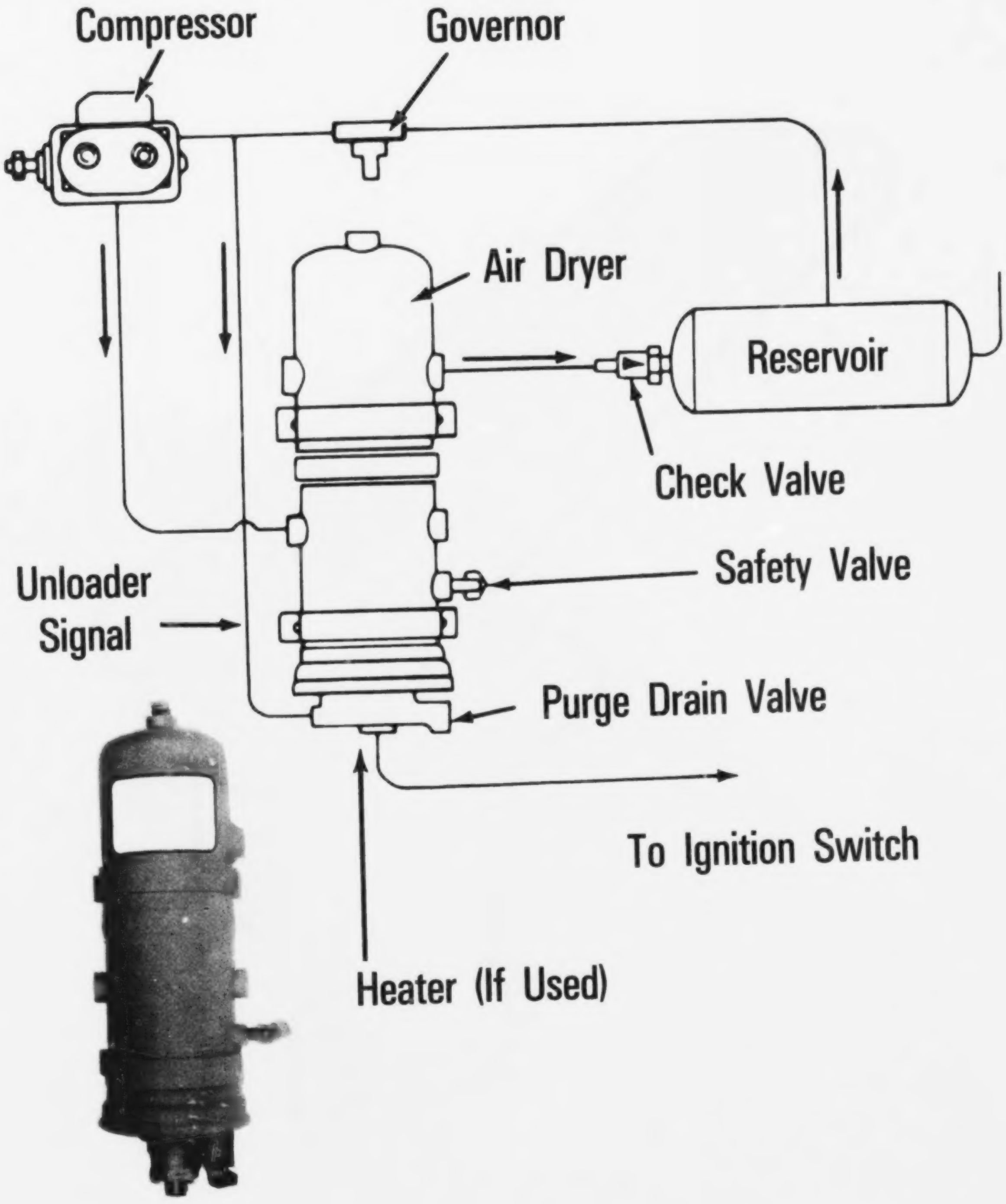
Visual 9.15

Alcohol Evaporator


Adapter
Unloader Port
Check Valve
Evaporator Assembly
Evaporator Assembly
Adapter
Alcohol Evaporator
Alcohol Reservoir

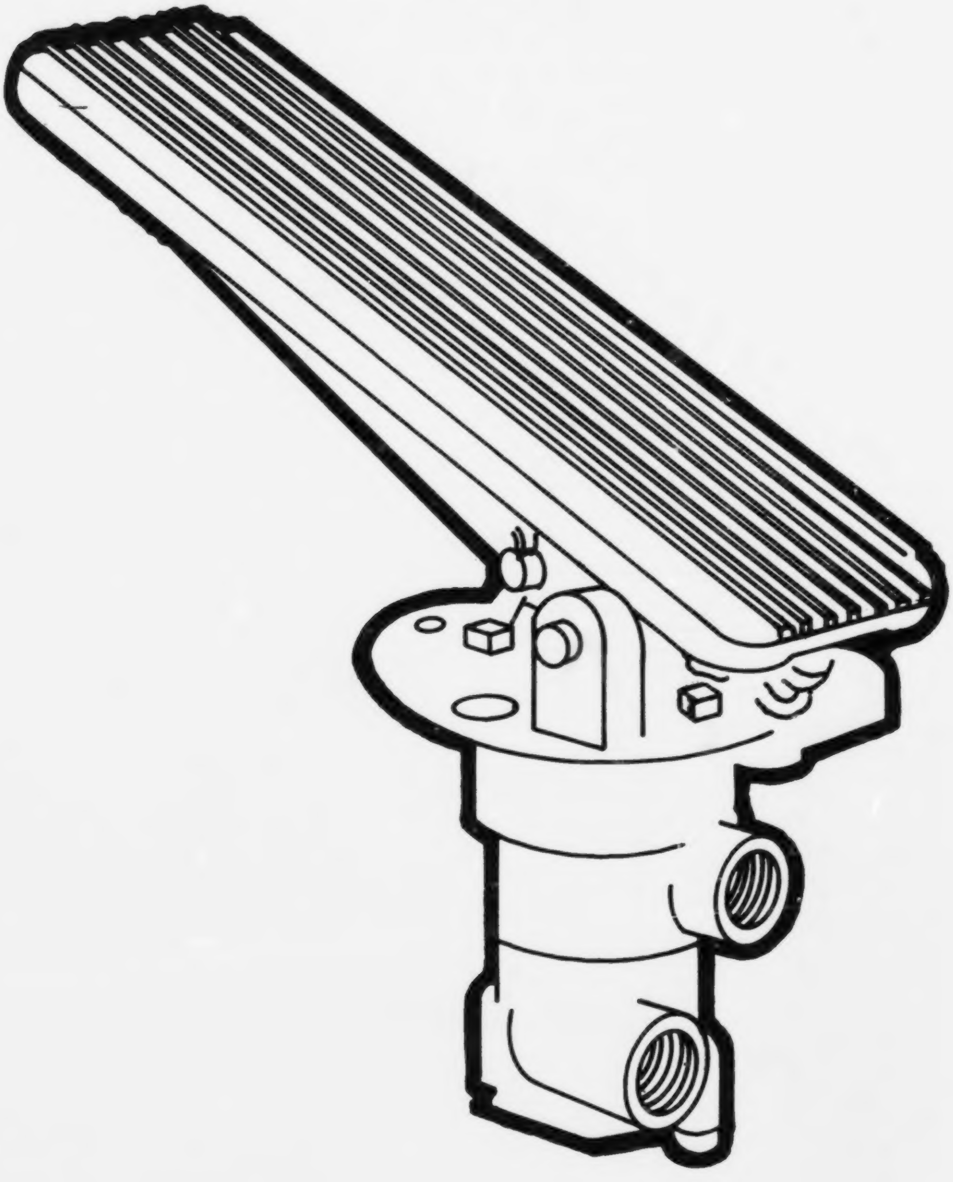
Visual 9.16

Air Dryer

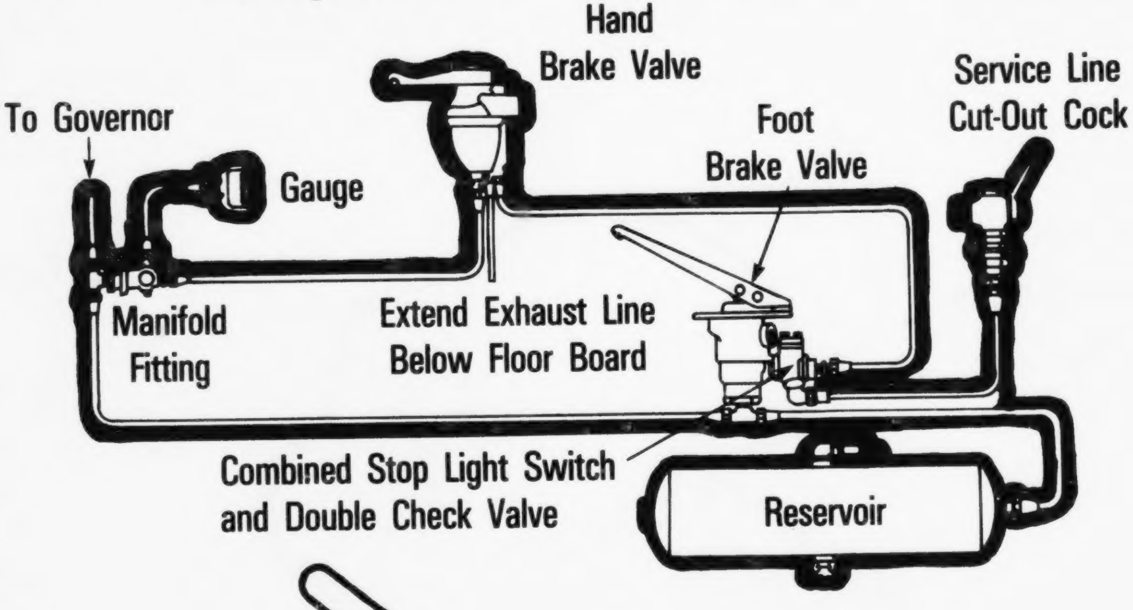

Compressor
Governor
Air Dryer
Reservoir
Check Valve
Safety Valve
Unloader
Signal
Purge Drain Valve
To Ignition Switch
Heater (If Used)

Visual 9.17

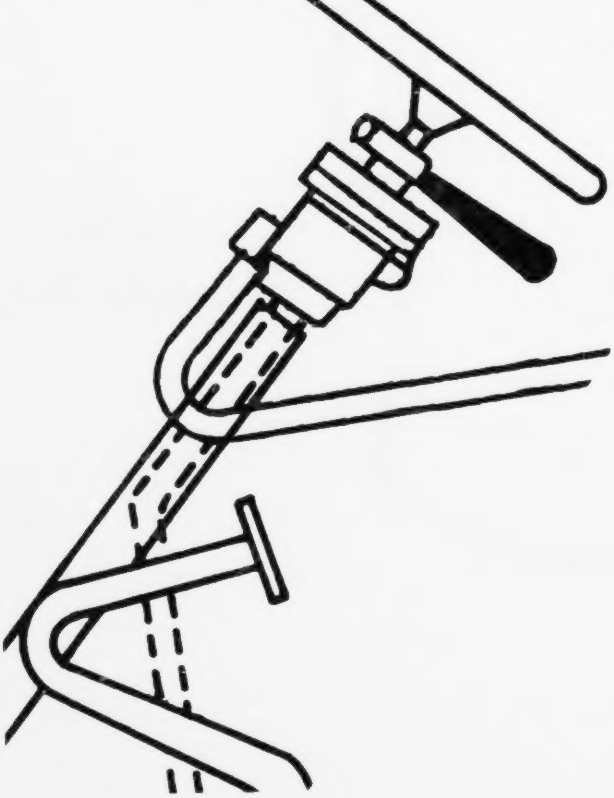
Treadle Valve

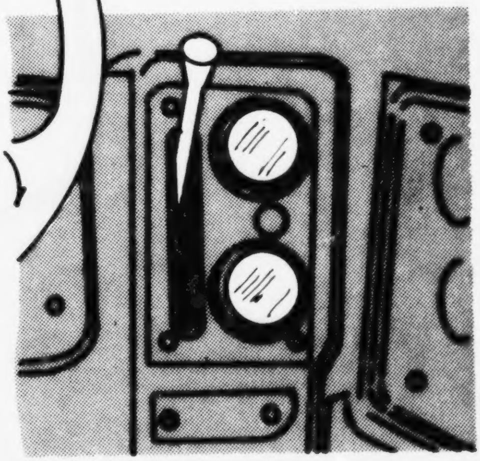


Independent Trailer Brake

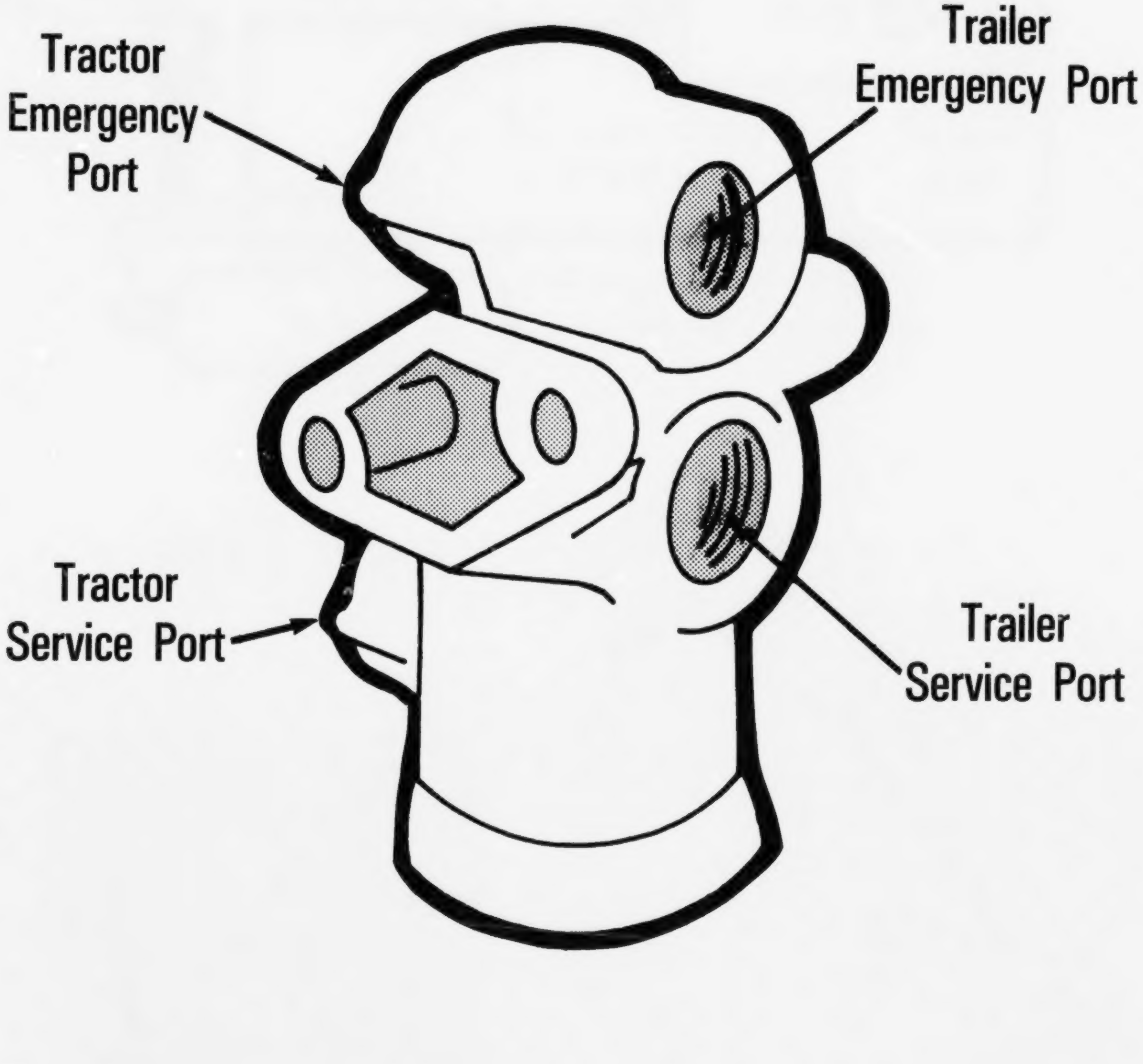

Hand
Brake Valve
Service Line
Cut-Out Cock
To Governor
Foot
Brake Valve
Gauge
Manifold
Fitting
Extend Exhaust Line
Below Floor Board
Combined Stop Light Switch
and Double Check Valve
Reservoir

Hand Valve



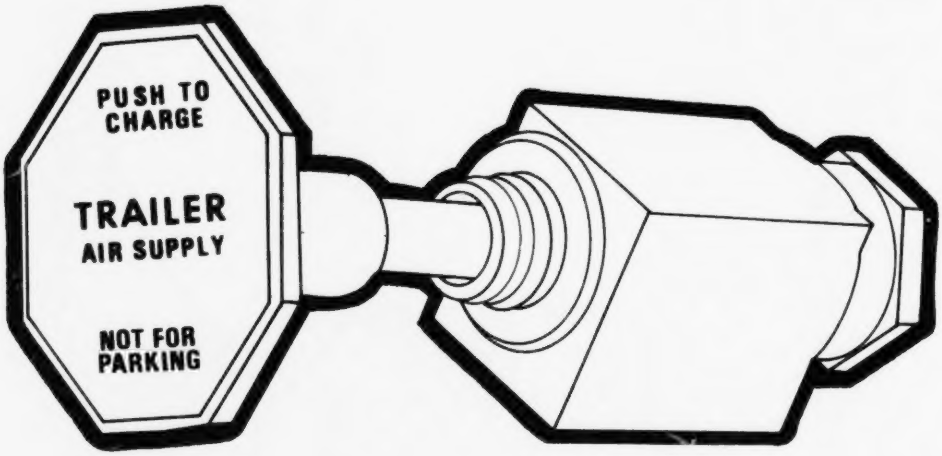


Tractor Protection Valve


Tractor Emergency Port
Trailer Emergency Port
Tractor Service Port
Trailer Service Port

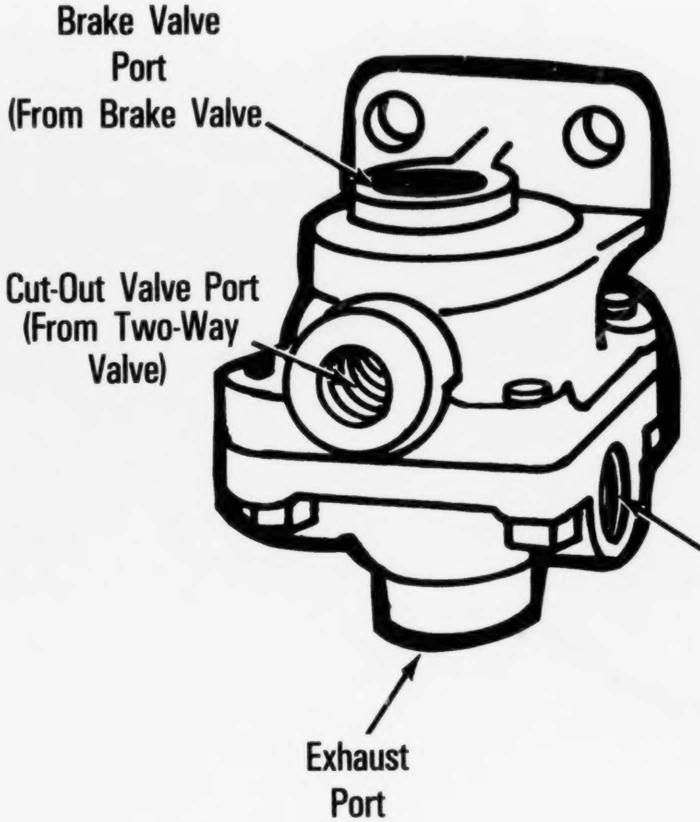
Visual 9.20

Emergency Valve

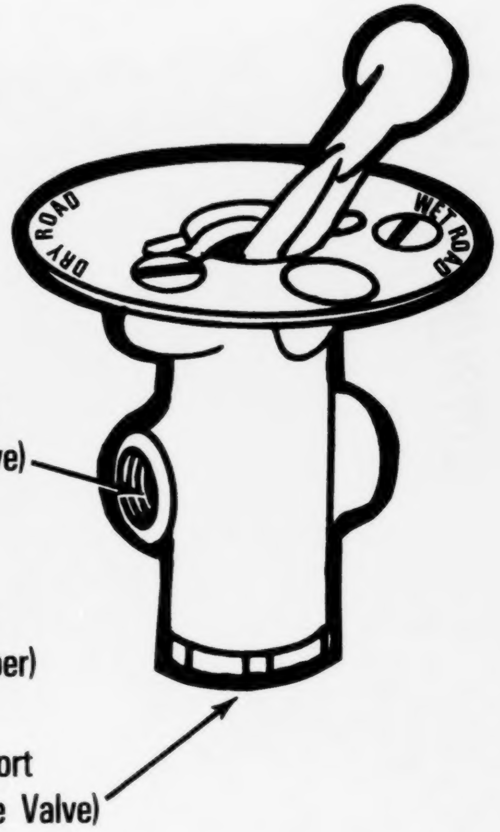

PUSH TO CHARGE
TRAILER AIR SUPPLY
NOT FOR PARKING

Front Brake Limiting Valve

Limiting & Quick Releasing Valve

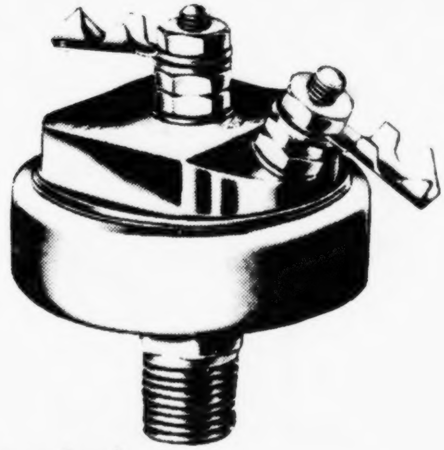

Brake Valve
Port
(From Brake Valve)
Cut-Out Valve Port
(From Two-Way
Valve)
Delivery Port
(To Brake Chamber)
Exhaust
Port

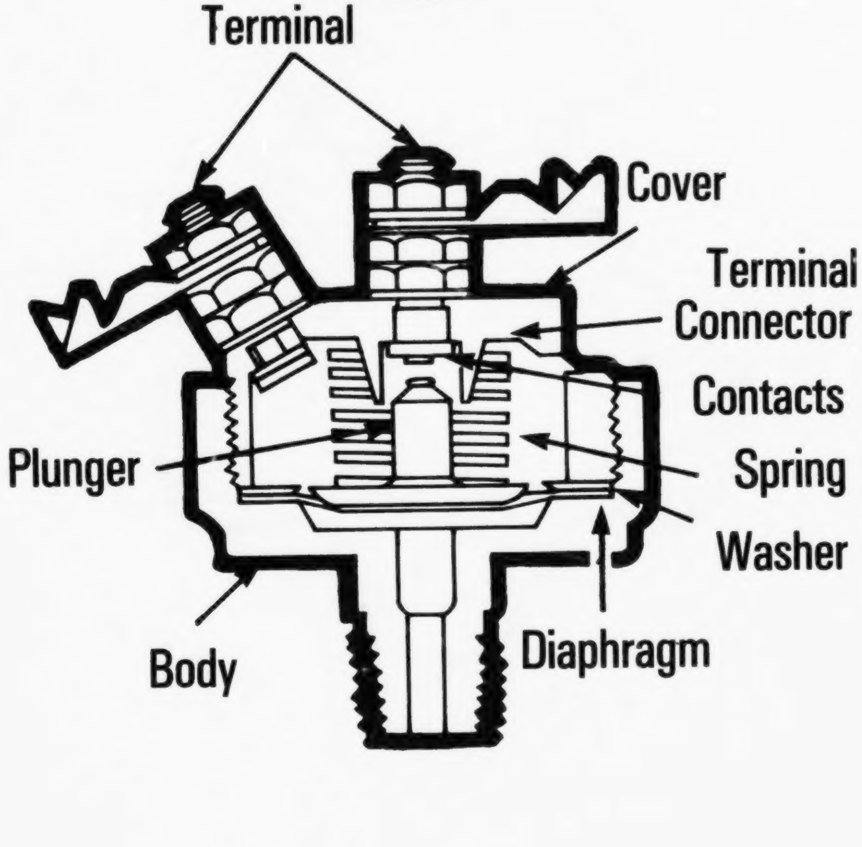
Control Valve


WET ROAD
DRY ROAD
Delivery Port
(To Limiting and
Quick Release Valve)
Inlet Port
(From Brake Valve)

Visual 9.22

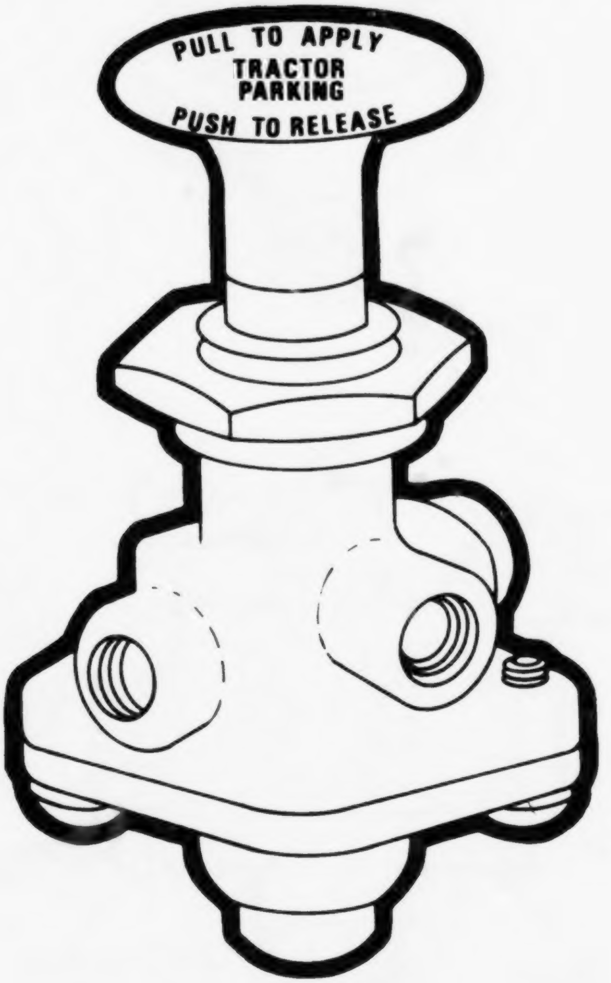
Stop Lamp Switch




Terminal
Cover
Terminal Connector
Contacts
Plunger
Spring
Washer
Body
Diaphragm

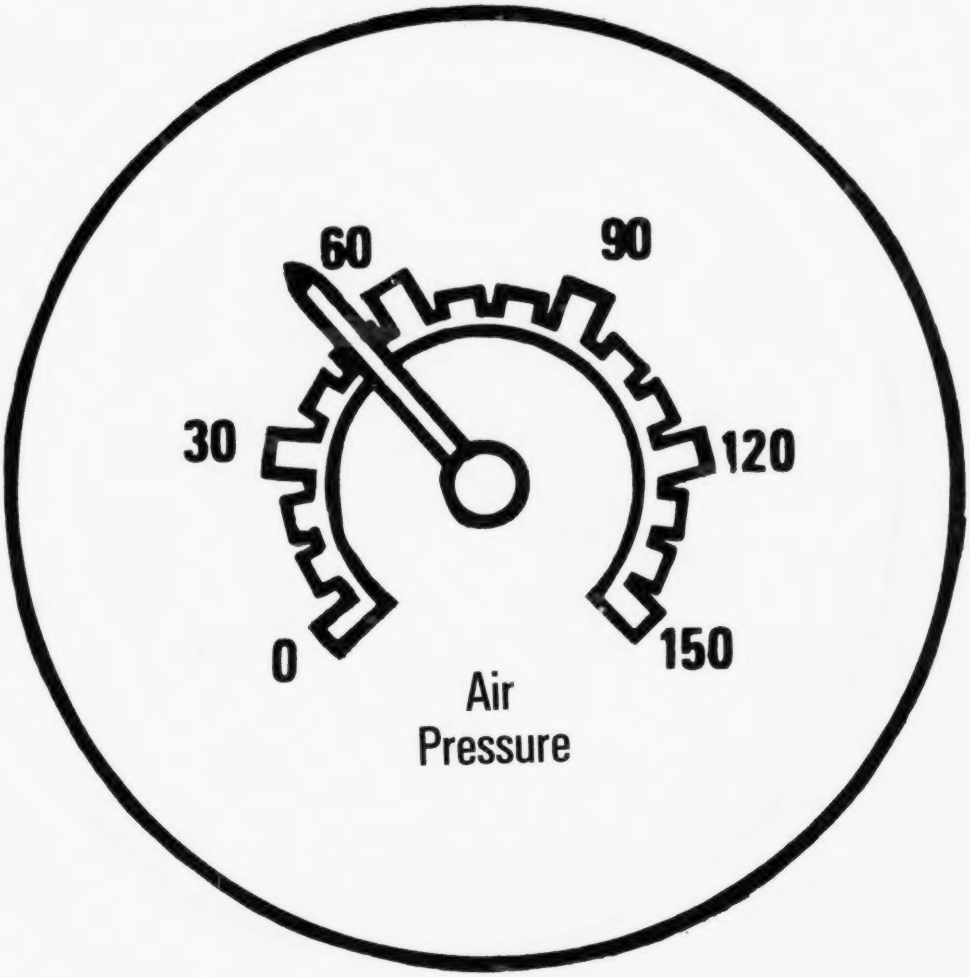
Visual 9.23

Parking Brake Valves

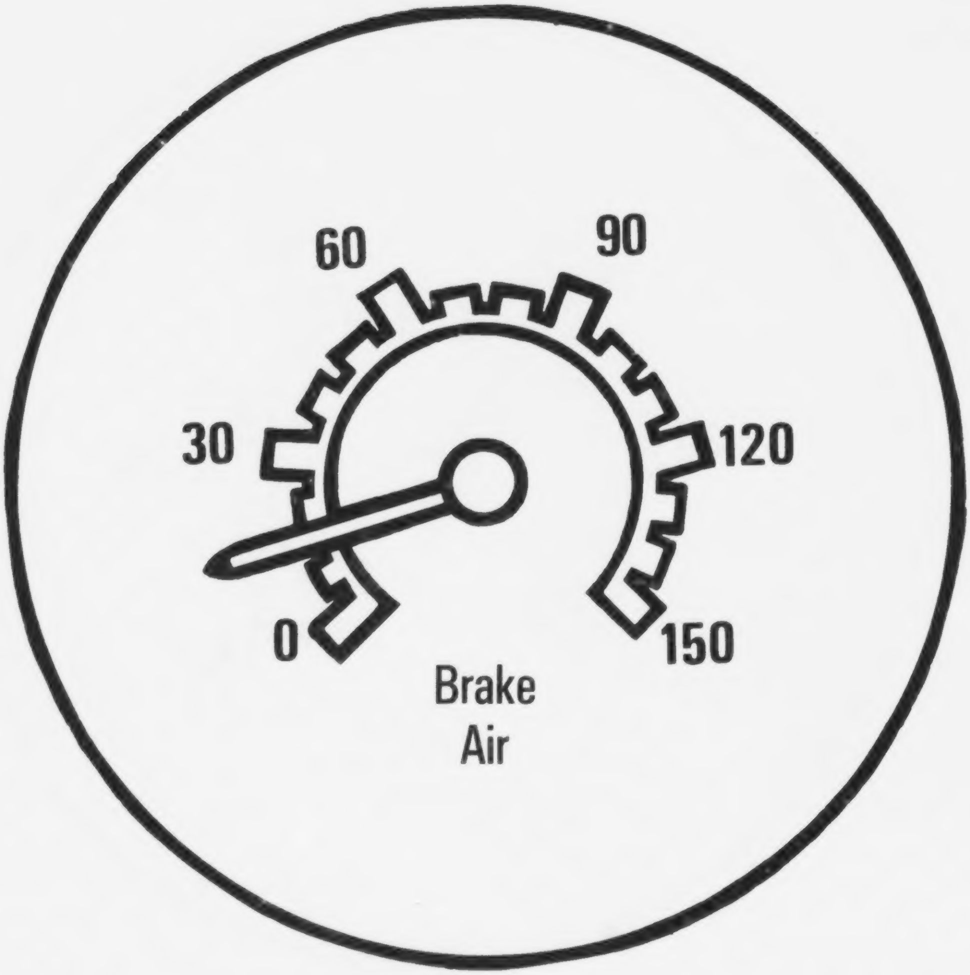

PULL TO APPLY
TRACTOR
PARKING
PUSH TO RELEASE

Visual 9.24

Air Reservoir Pressure Gauge

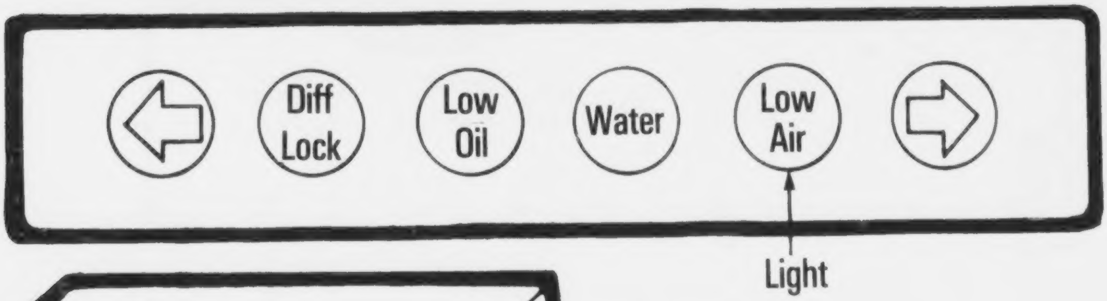

0
30
60
90
120
150
Air
Pressure

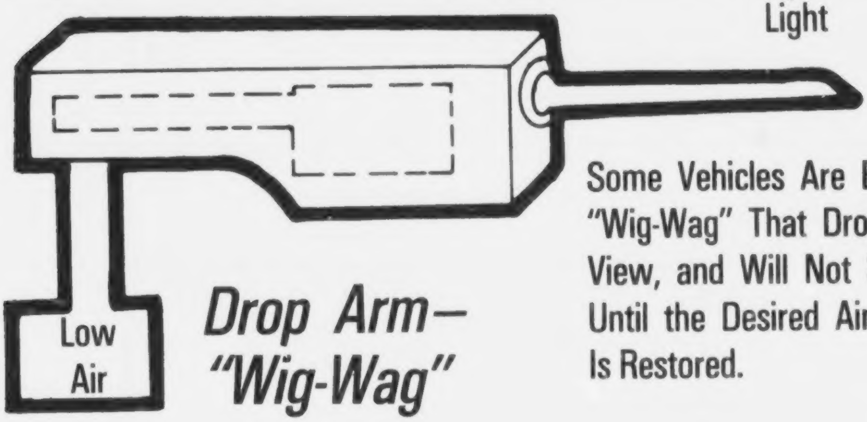
Air Application Gauge


0
30
60
90
120
150
Brake
Air

Visual 9.26

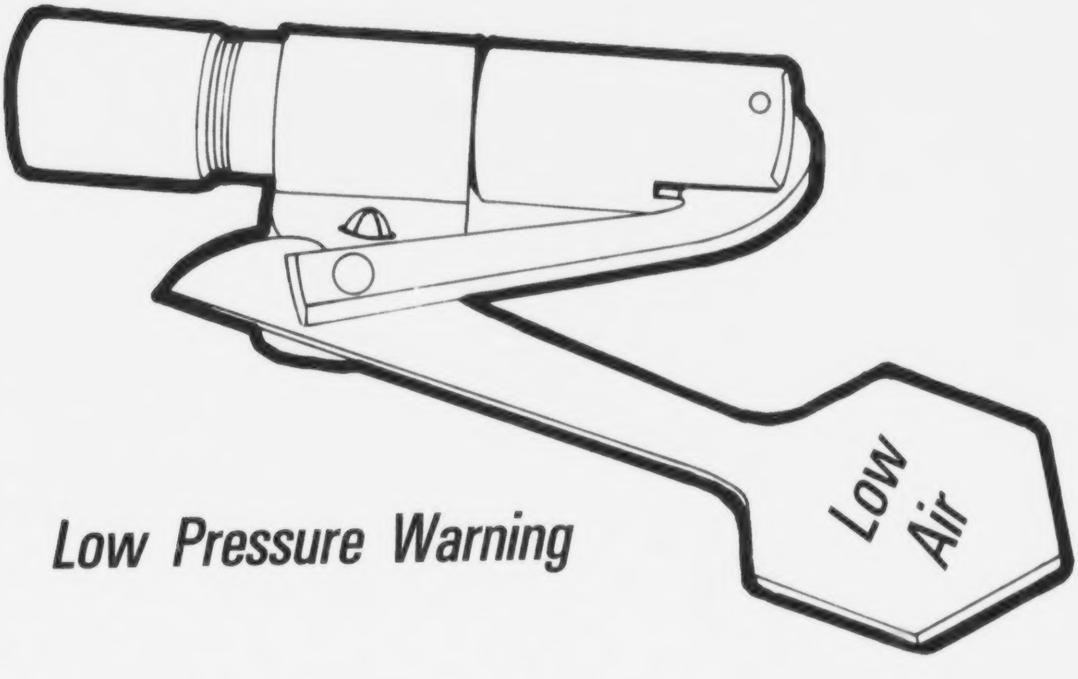
Low Air Pressure Warning Devices


Diff Lock
Low Oil
Water
Low Air
Light



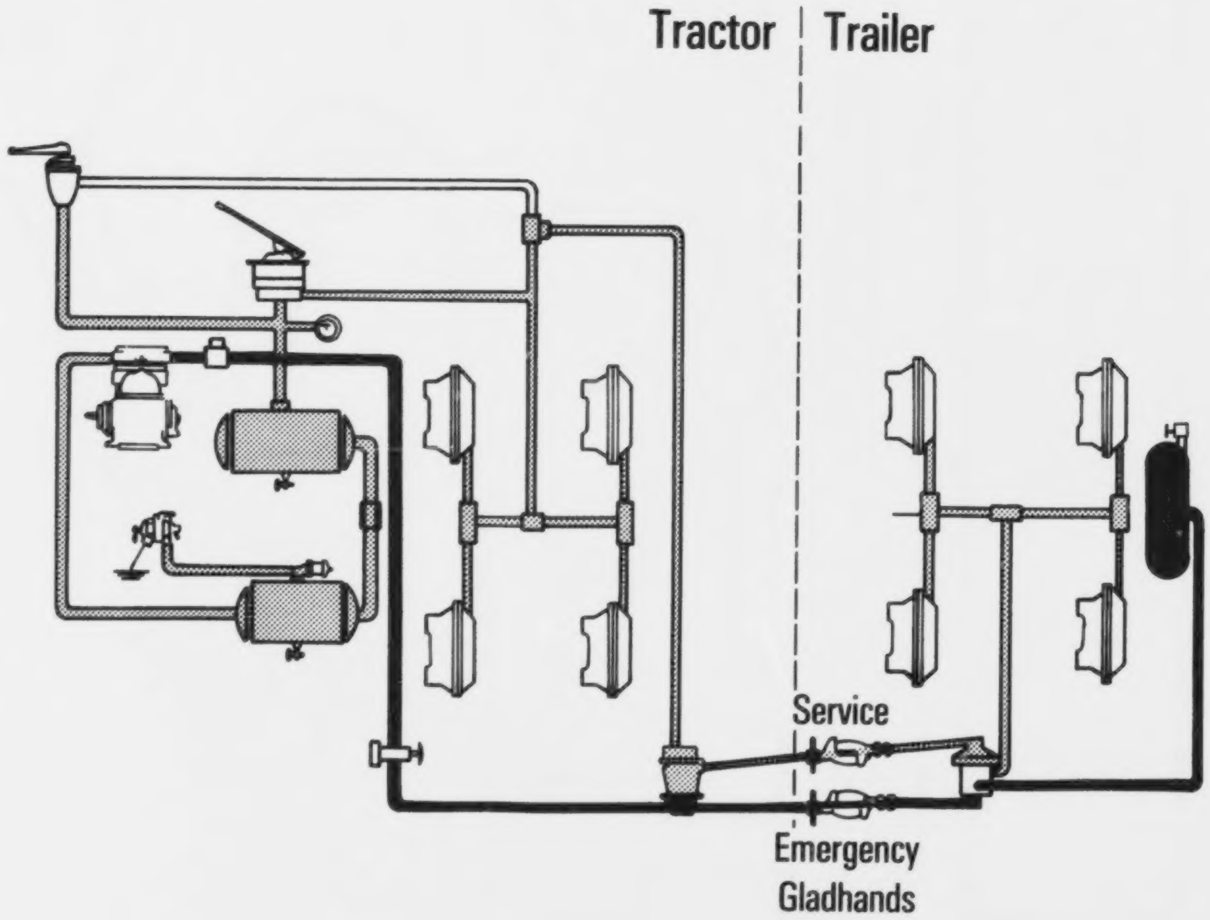
Drop Arm—
"Wig-Wag"

Some Vehicles Are Equipped With a "Wig-Wag" That Drops Into the Driver's View, and Will Not Stay Up in Place Until the Desired Air Pressure Is Restored.

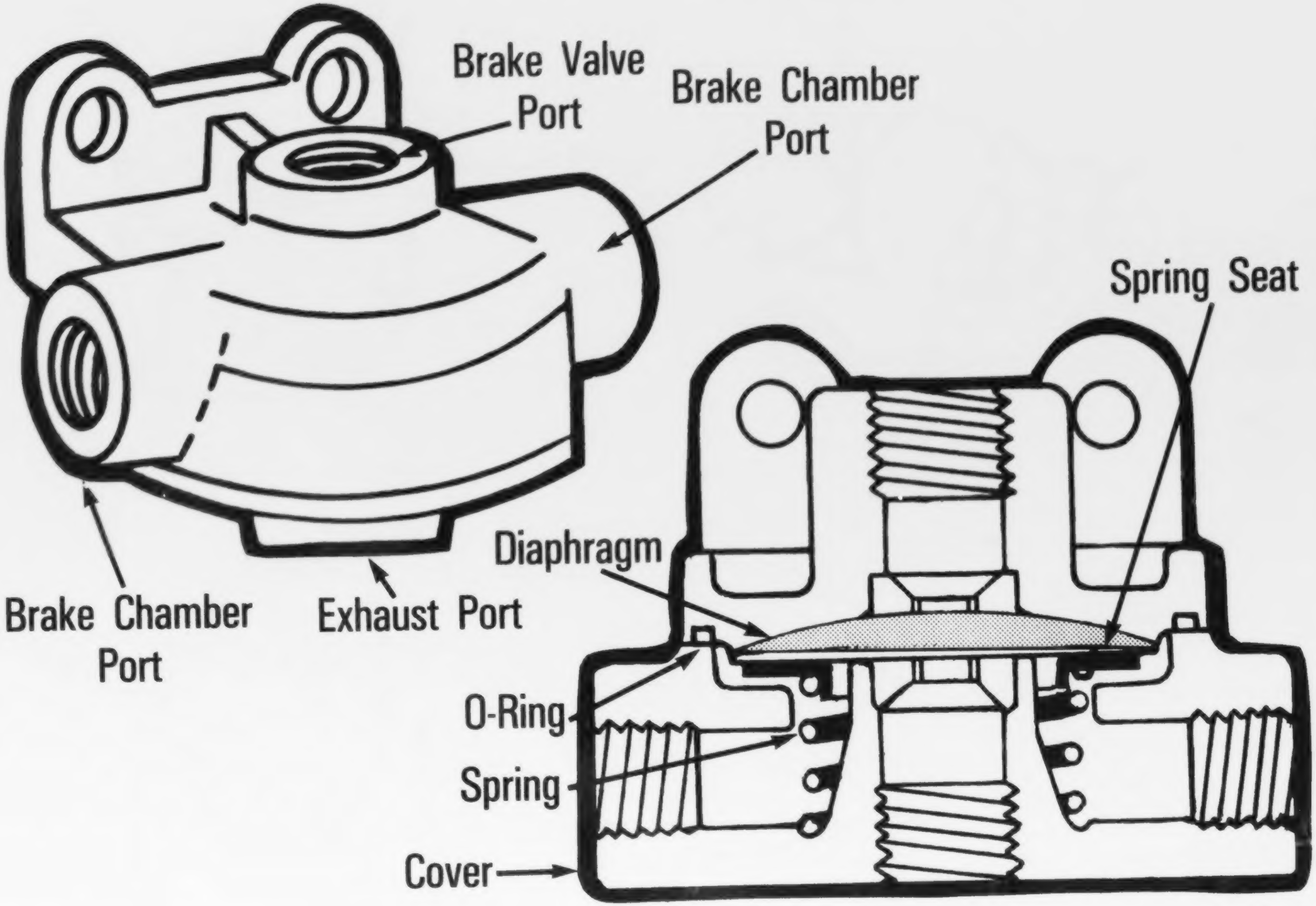


Low Pressure Warning

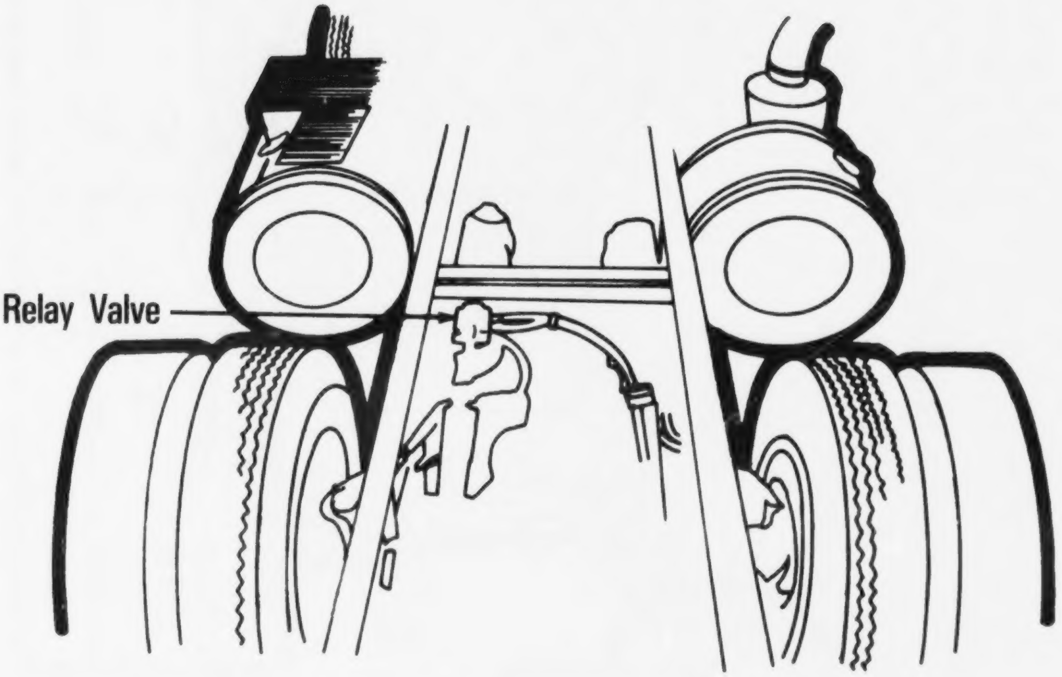
Service and Emergency Air Lines

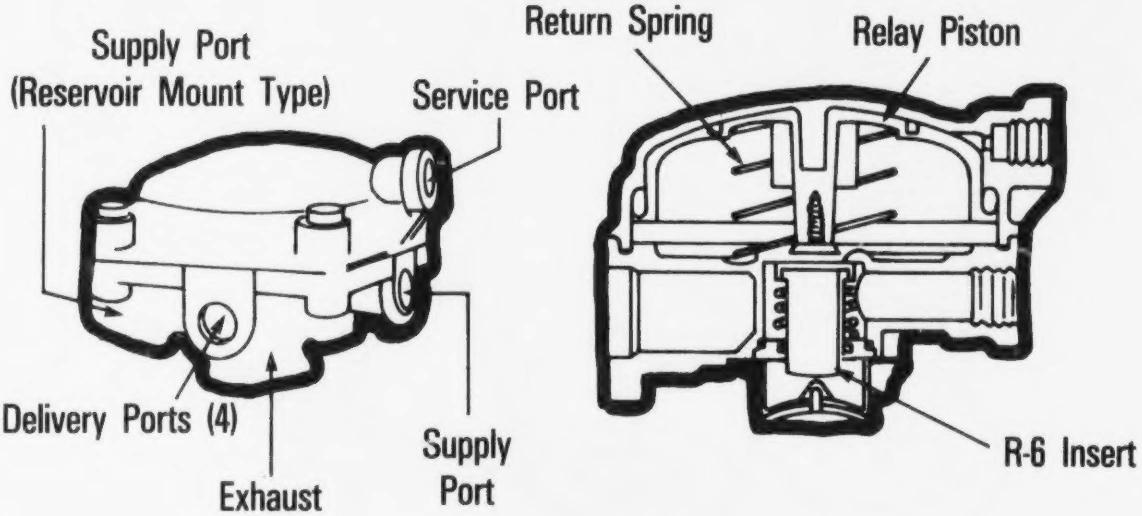

Tractor
Trailer
Service
Emergency
Gladhands

Quick Release Valves

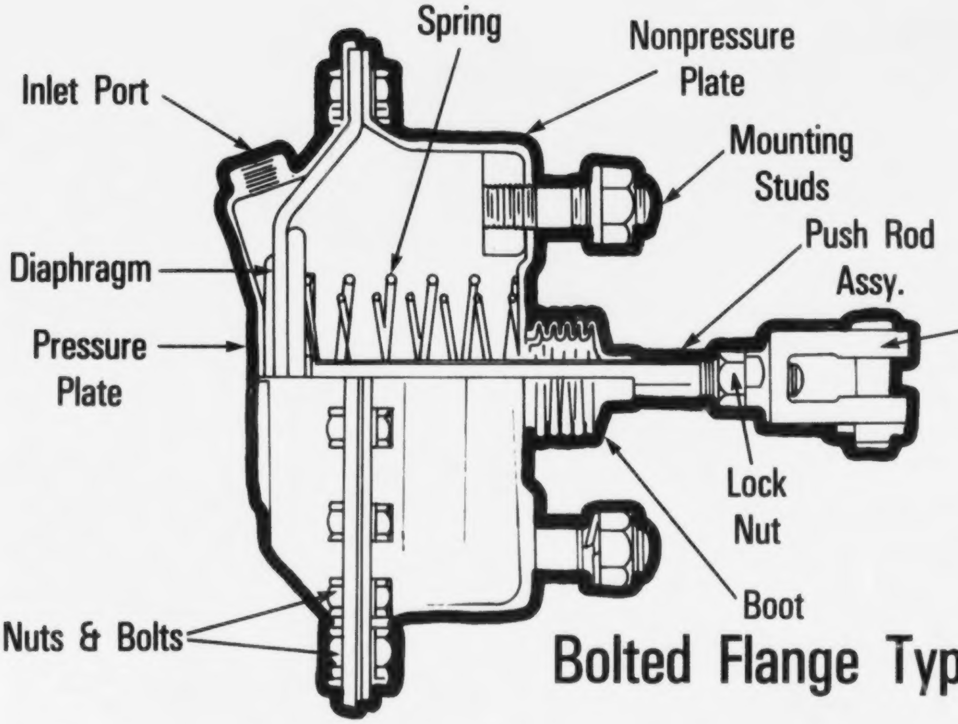

Brake Valve Port
Brake Chamber Port
Brake Chamber Port
Exhaust Port
Spring Seat
Diaphragm
O-Ring
Spring
Cover

Relay Valve

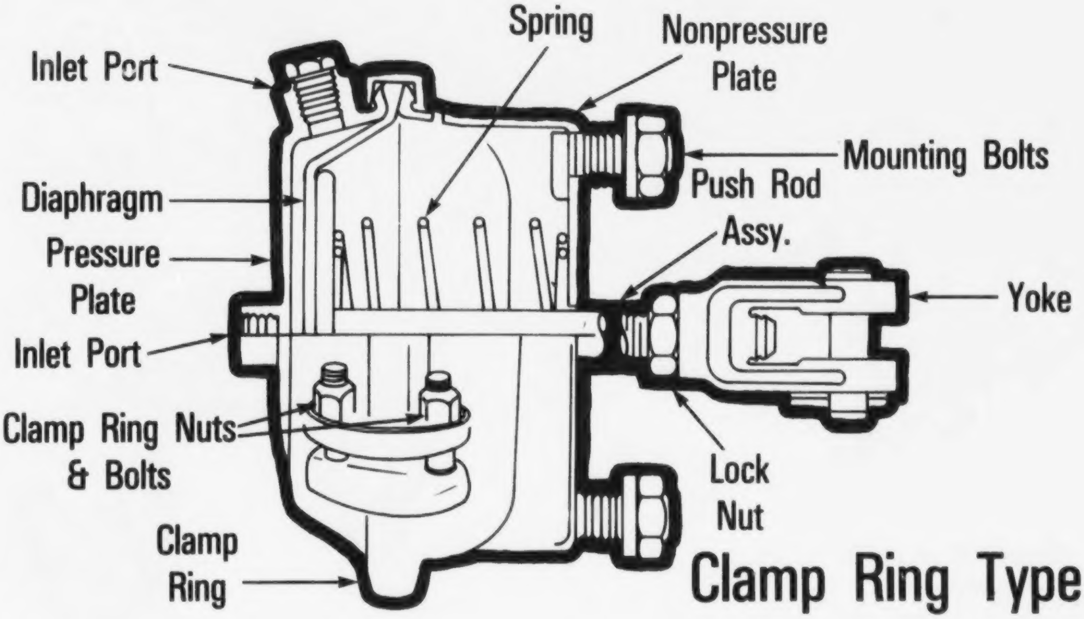

Relay Valve


Supply Port
(Reservoir Mount Type)
Service Port
Delivery Ports (4)
Exhaust
Supply
Port
Return Spring
Relay Piston
R-6 Insert

Brake Chambers


Spring
Nonpressure Plate
Inlet Port
Mounting Studs
Push Rod Assy.
Diaphragm
Yoke
Pressure Plate
Lock Nut
Boot
Nuts & Bolts

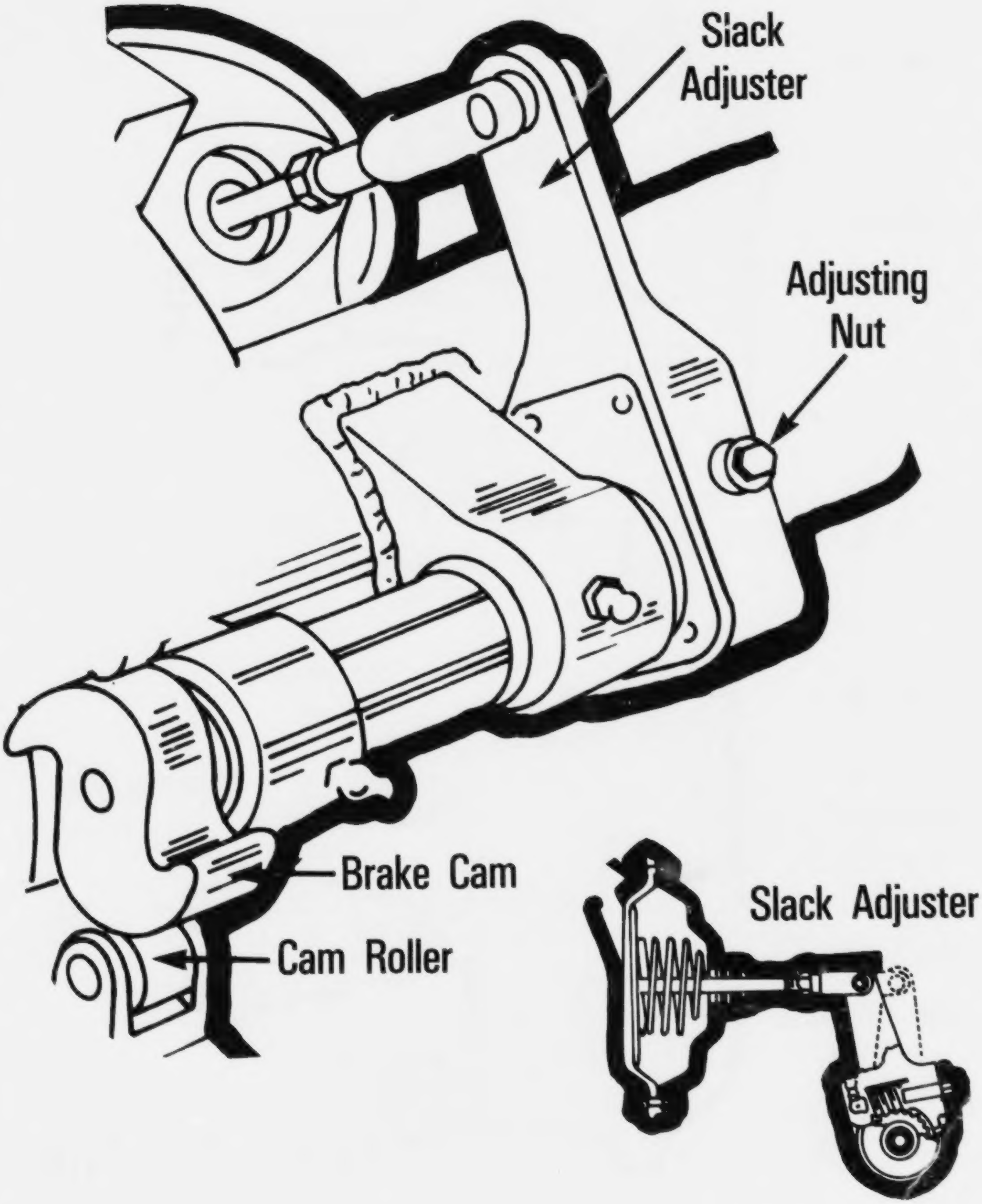
Bolted Flange Type


Spring
Nonpressure Plate
Inlet Port
Mounting Bolts
Diaphragm
Push Rod Assy.
Pressure Plate
Yoke
Inlet Port
Clamp Ring Nuts & Bolts
Lock Nut
Clamp Ring

Clamp Ring Type

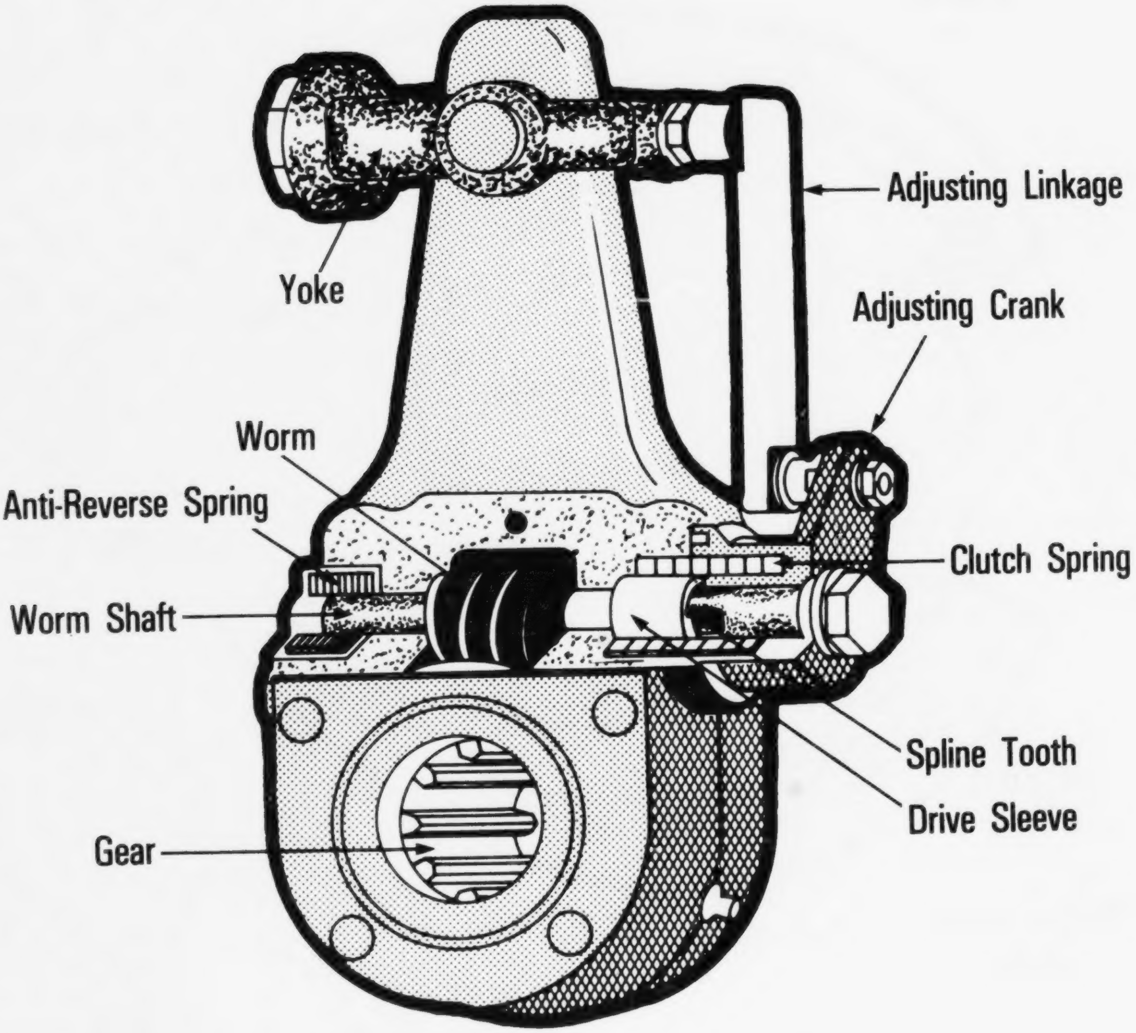
Visual 9.31

Manual Slack Adjuster


Slack Adjuster
Adjusting Nut
Brake Cam
Cam Roller
Slack Adjuster

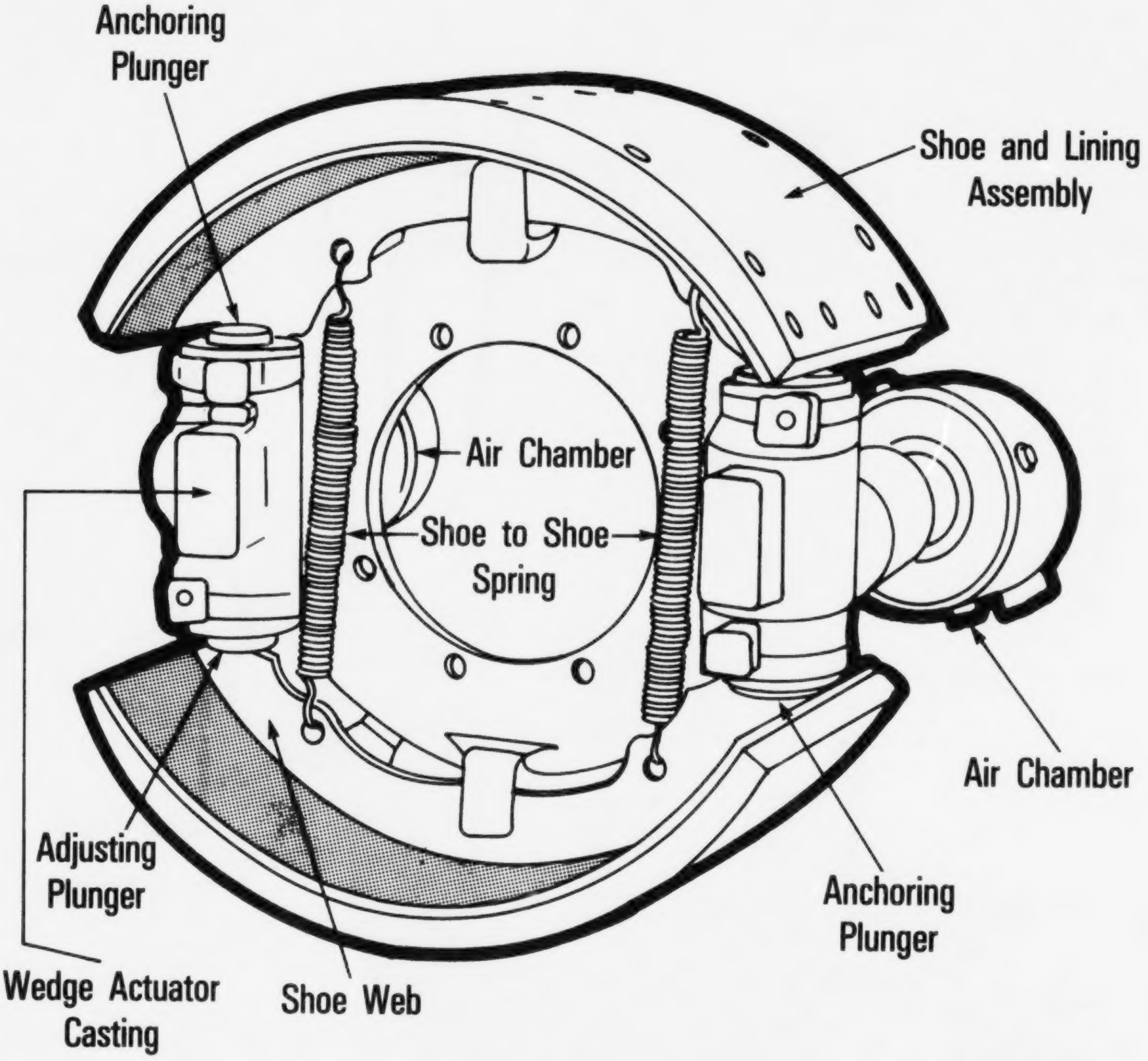
Visual 9.32

Automatic Slack Adjuster

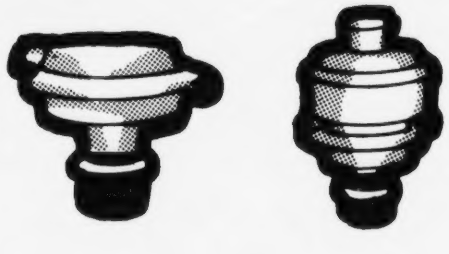

Adjusting Linkage
Yoke
Adjusting Crank
Worm
Anti-Reverse Spring
Clutch Spring
Worm Shaft
Spline Tooth
Drive Sleeve
Gear

Visual 9.33

Wedge Actuated Drum Brake

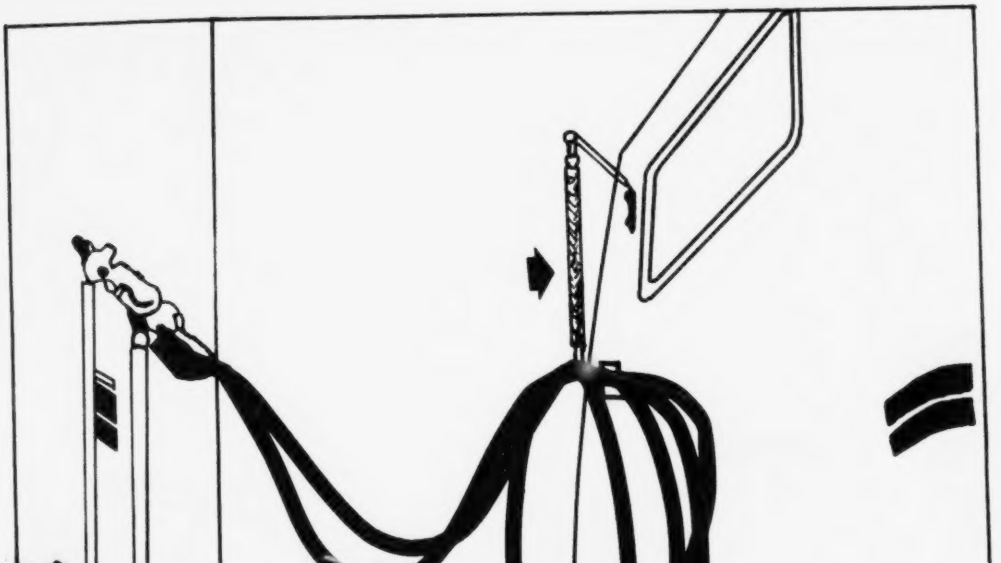

Anchoring Plunger
Shoe and Lining Assembly
Air Chamber
Shoe to Shoe Spring
Air Chamber
Adjusting Plunger
Anchoring Plunger
Wedge Actuator Casting
Shoe Web

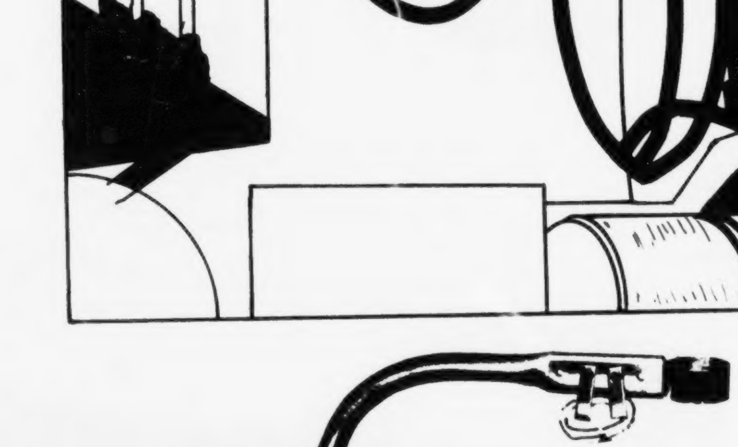
Wedge Brake Acutators

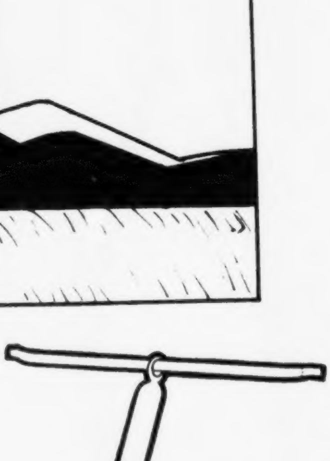


Visual 9.34

Bracket and Spring Air Hose Keeper

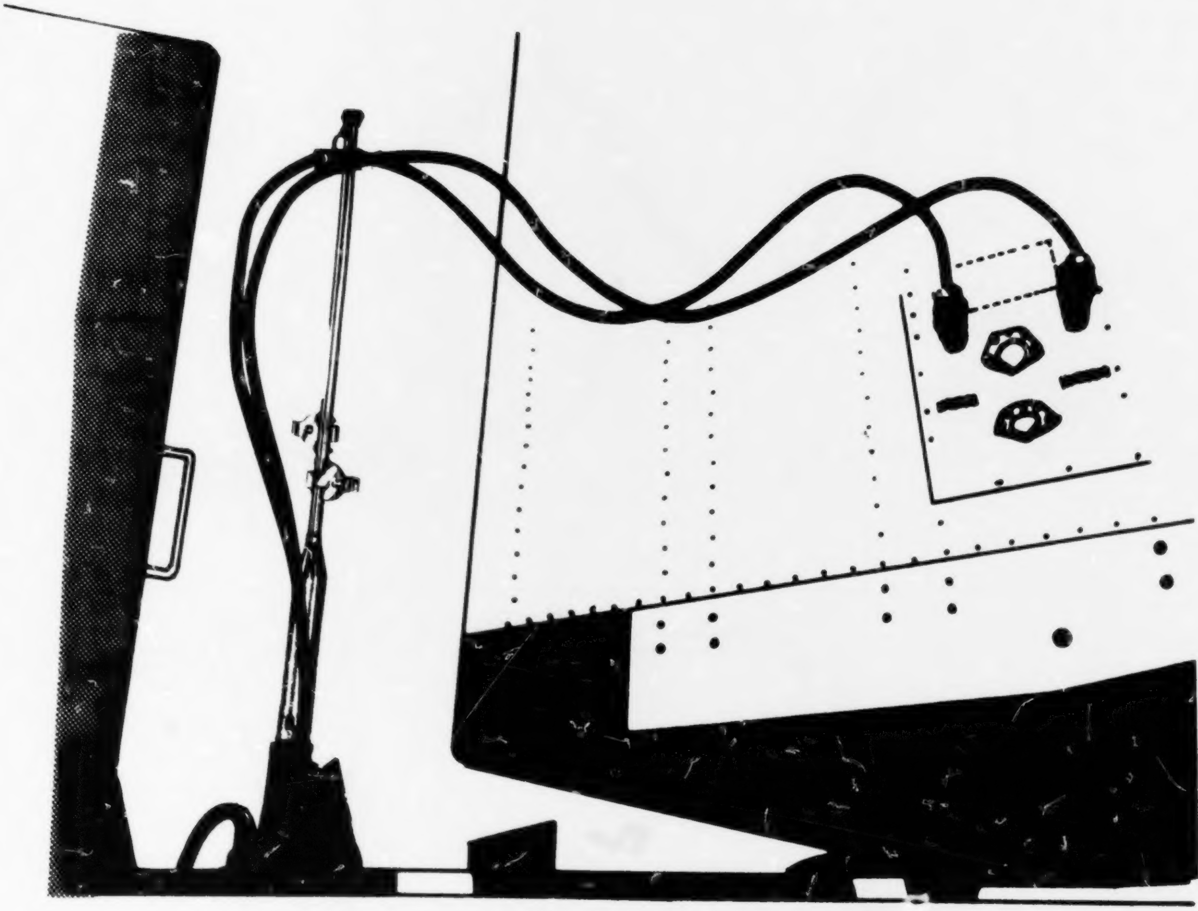






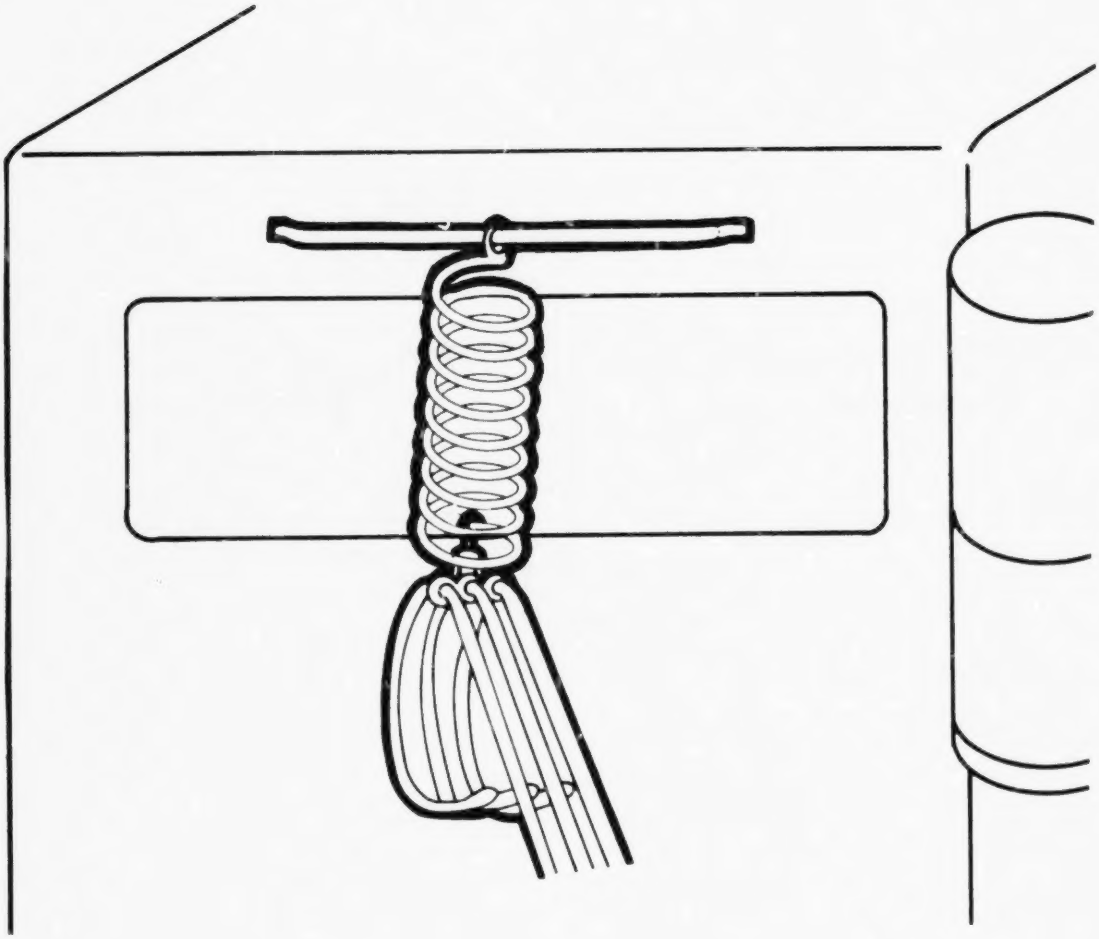
Visual 9.35

Pogo Stick Air Hose Keeper

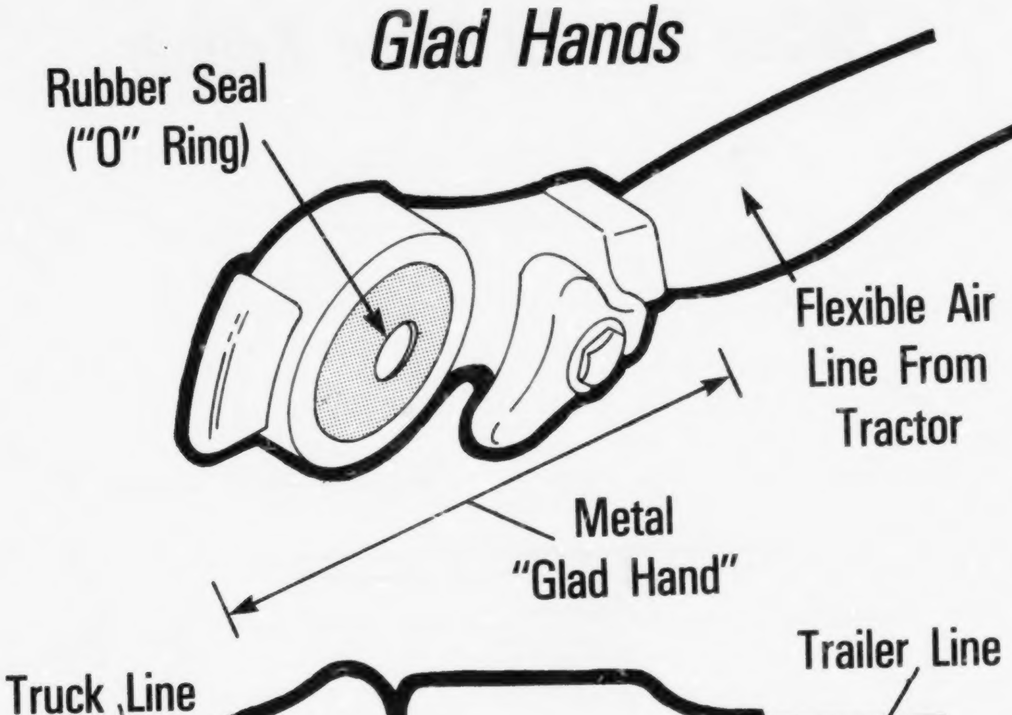


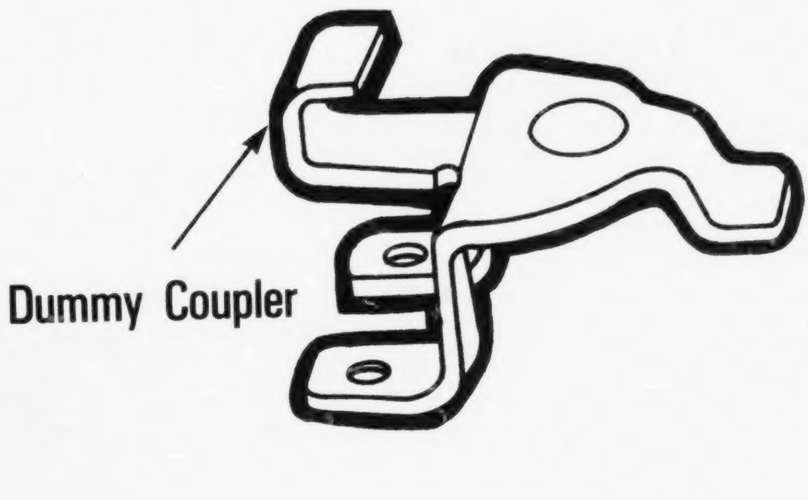
Visual 9.36

Slider Bar Air Hose Keeper



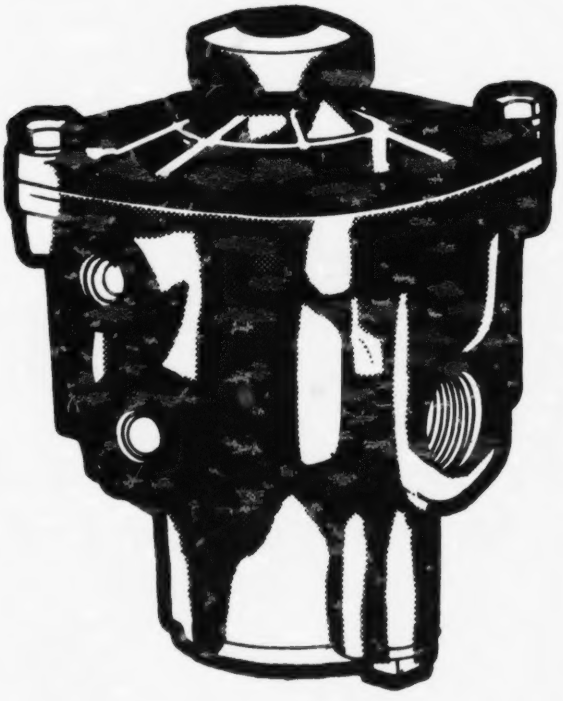
Glad Hands

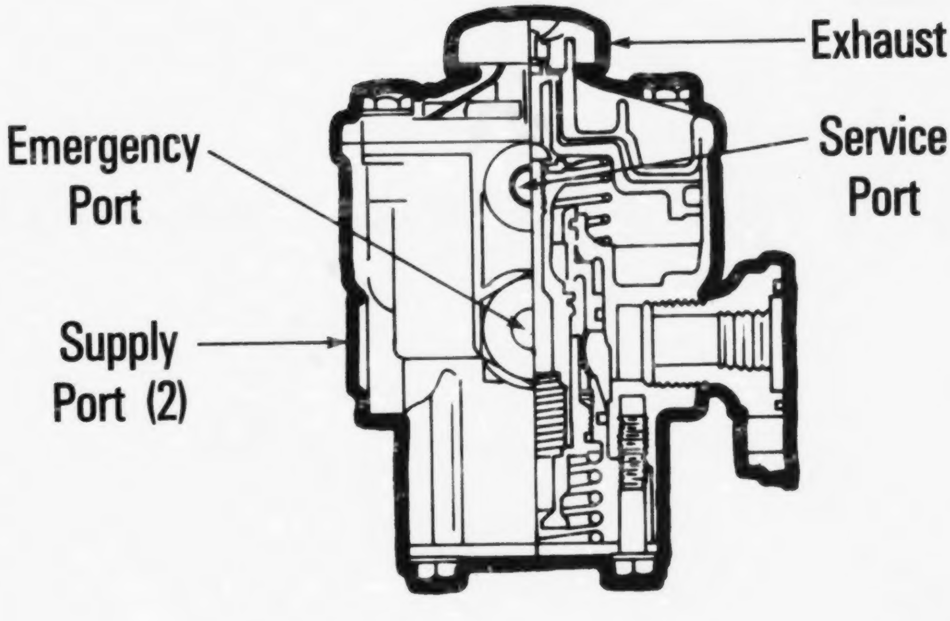

Rubber Seal
("O" Ring)
Flexible Air Line From Tractor
Metal "Glad Hand"
Truck Line
Trailer Line
"O" Ring


Dummy Coupler

Visual 9.38

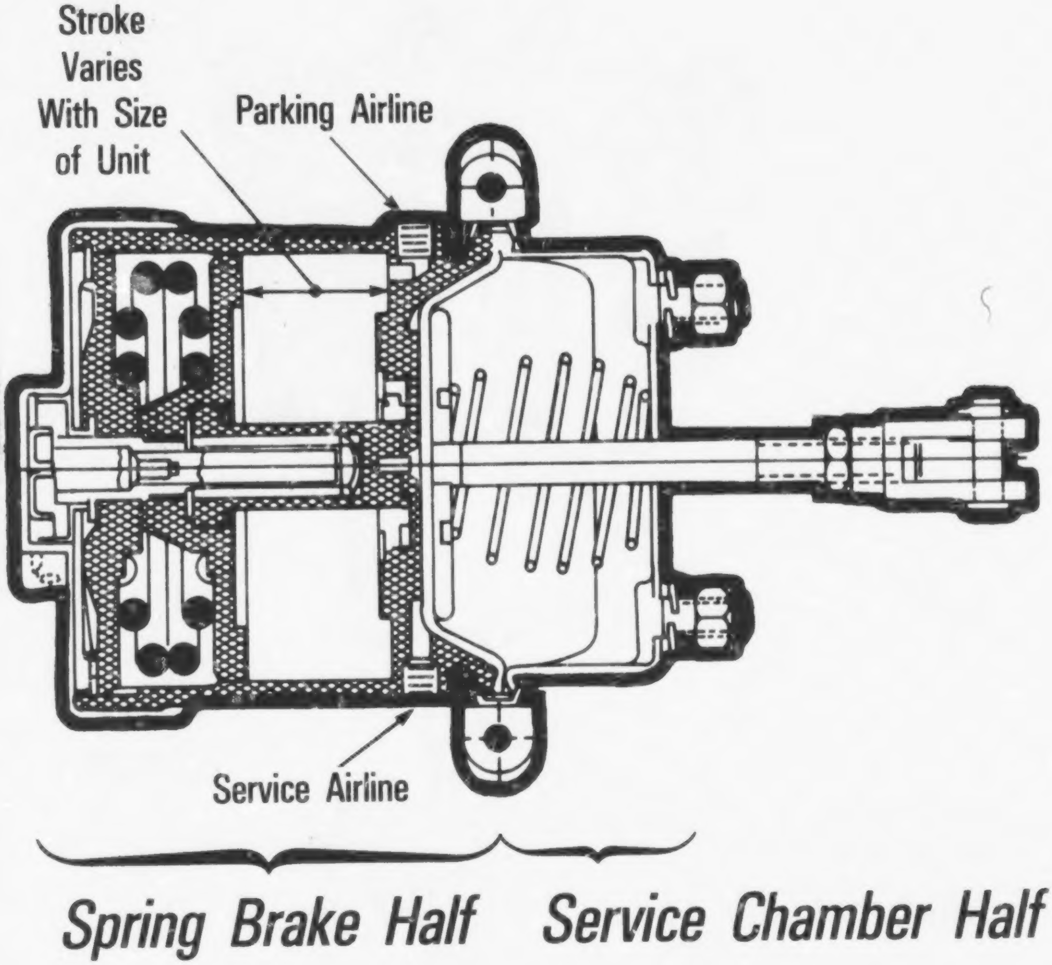
Relay Emergency Valve



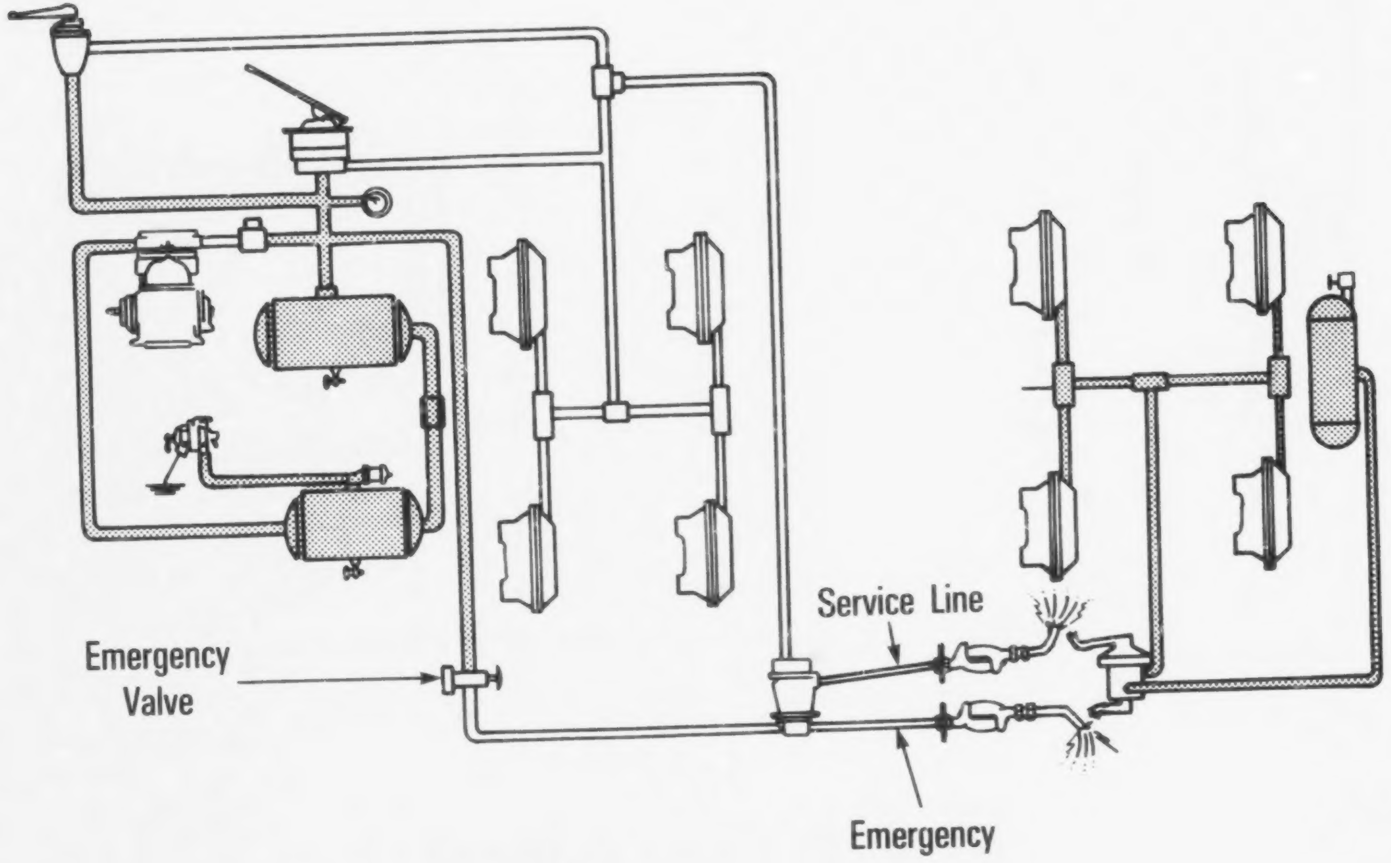

Exhaust
Emergency Port
Service Port
Supply Port (2)

Visual 9.39

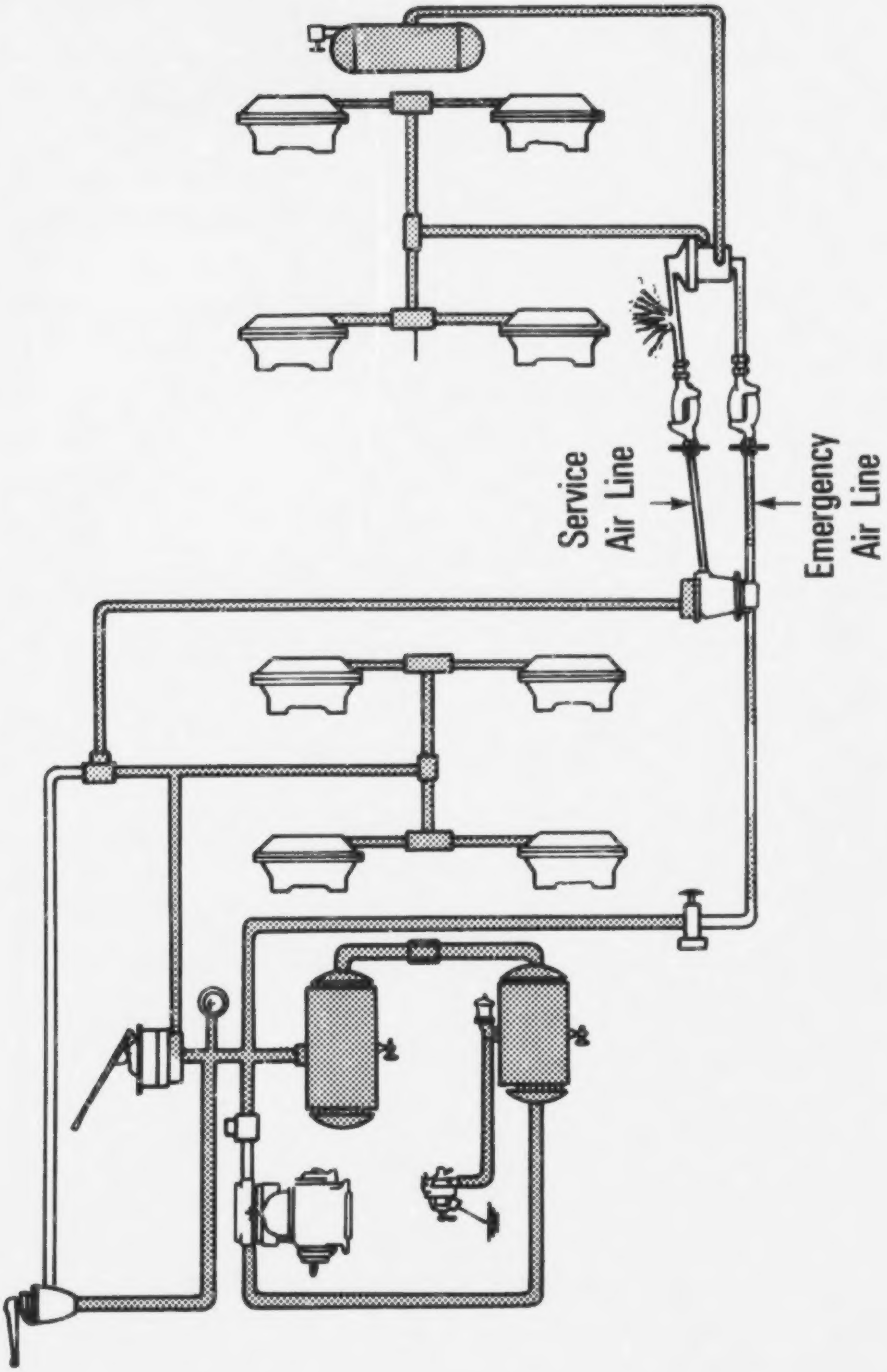
"Fail Safe" Spring Brakes


Stroke Varies With Size of Unit
Parking Airline
Service Airline
Spring Brake Half
Service Chamber Half

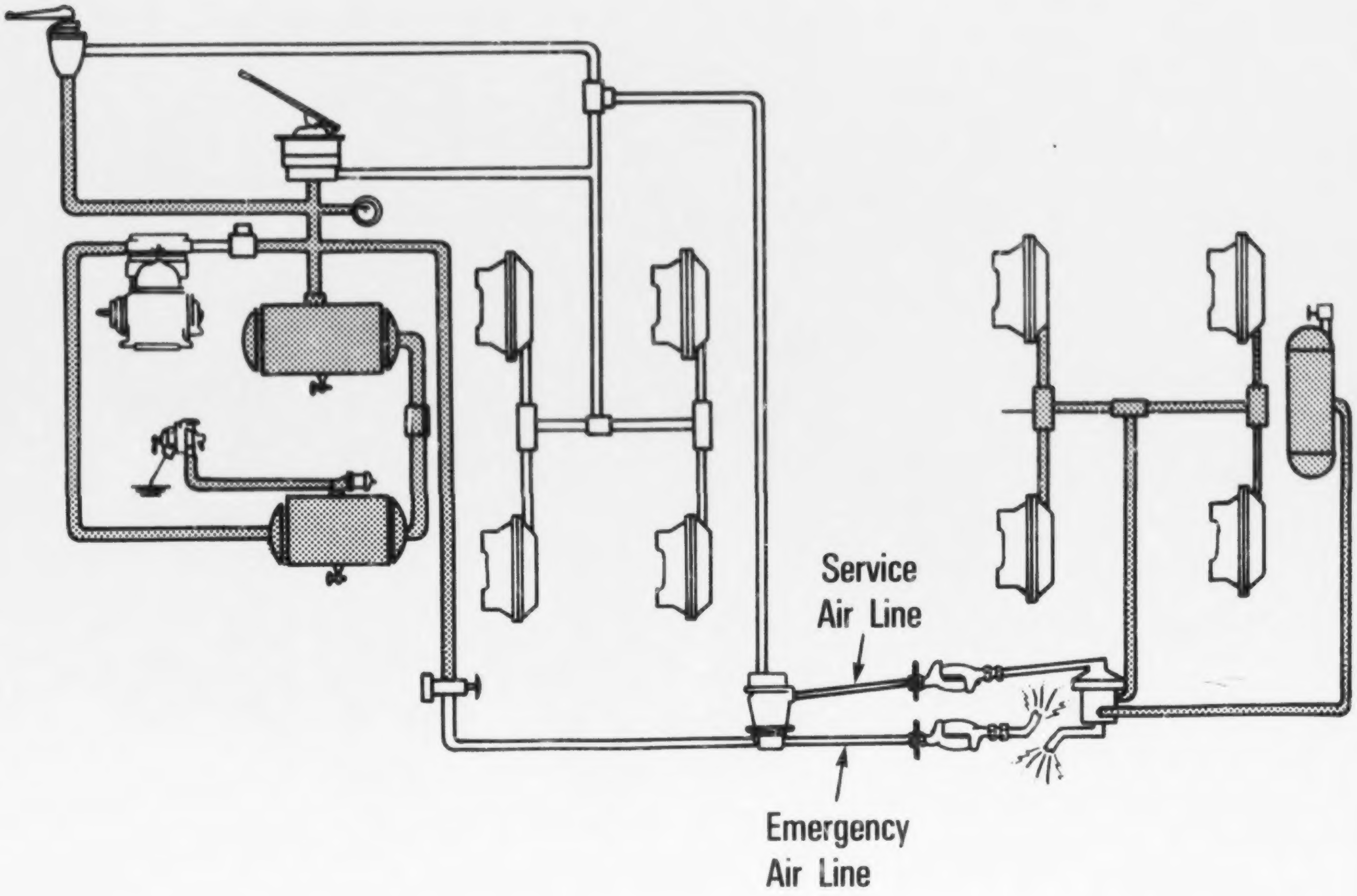
Trailer Breakaway


Service Line
Emergency Valve
Emergency

Service Line Rupture

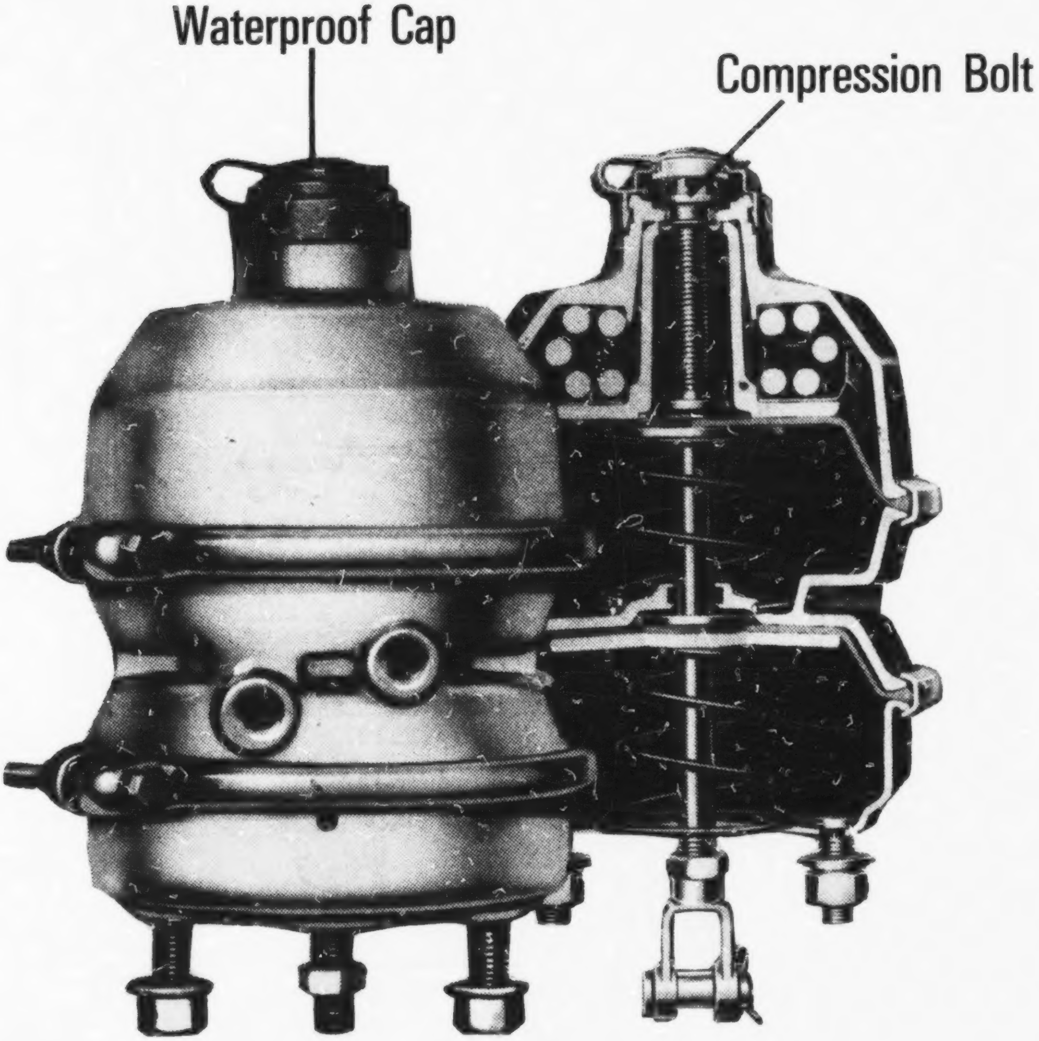

Service
Air Line
Emergency
Air Line

Emergency Line Rupture


Service
Air Line
Emergency
Air Line

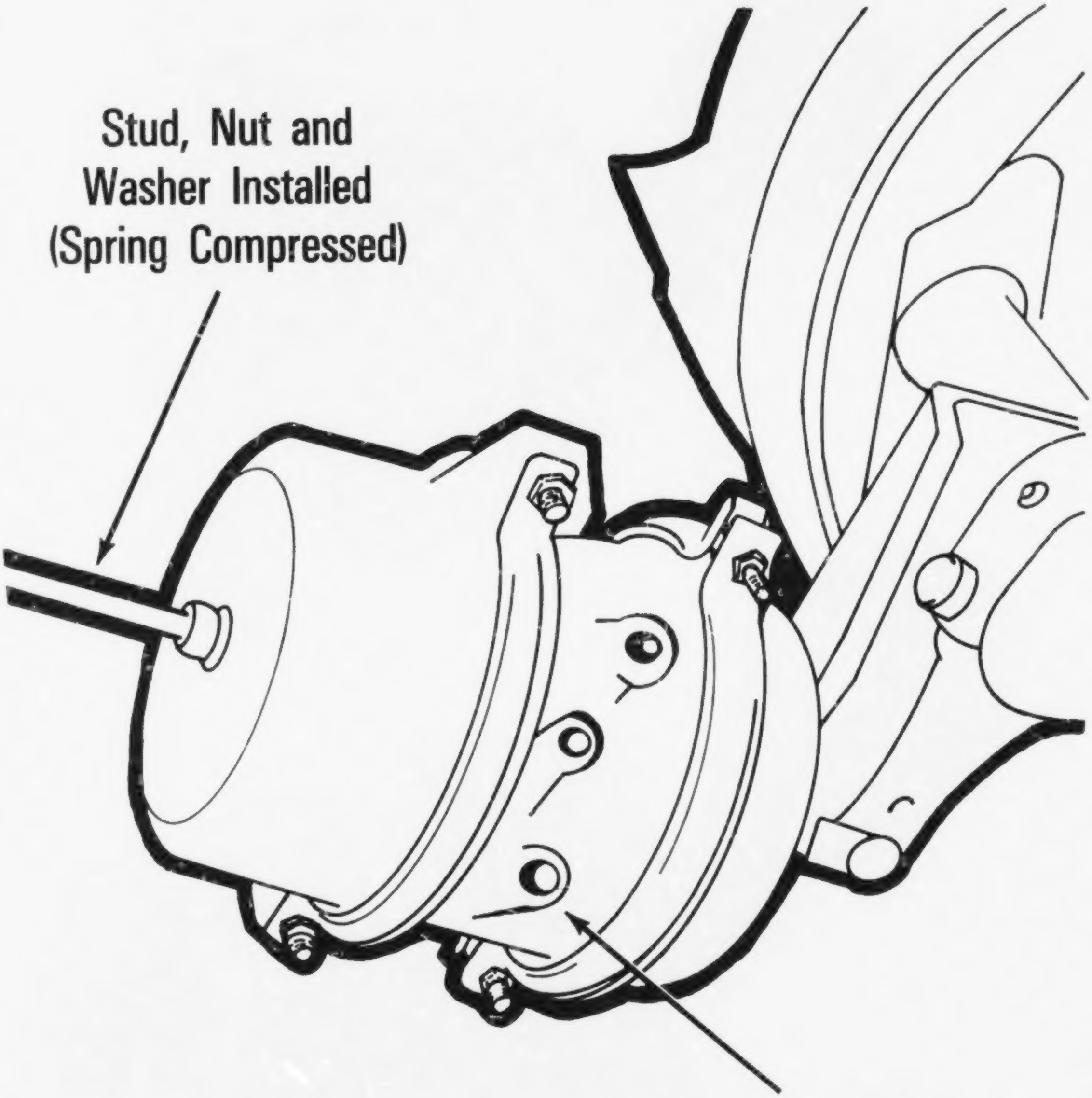
Visual 9.43

Releasing "Stopgard" Type Spring Brakes


Waterproof Cap
Compression Bolt

Visual 9.44

Releasing "Anchorlok" Type Spring Brakes

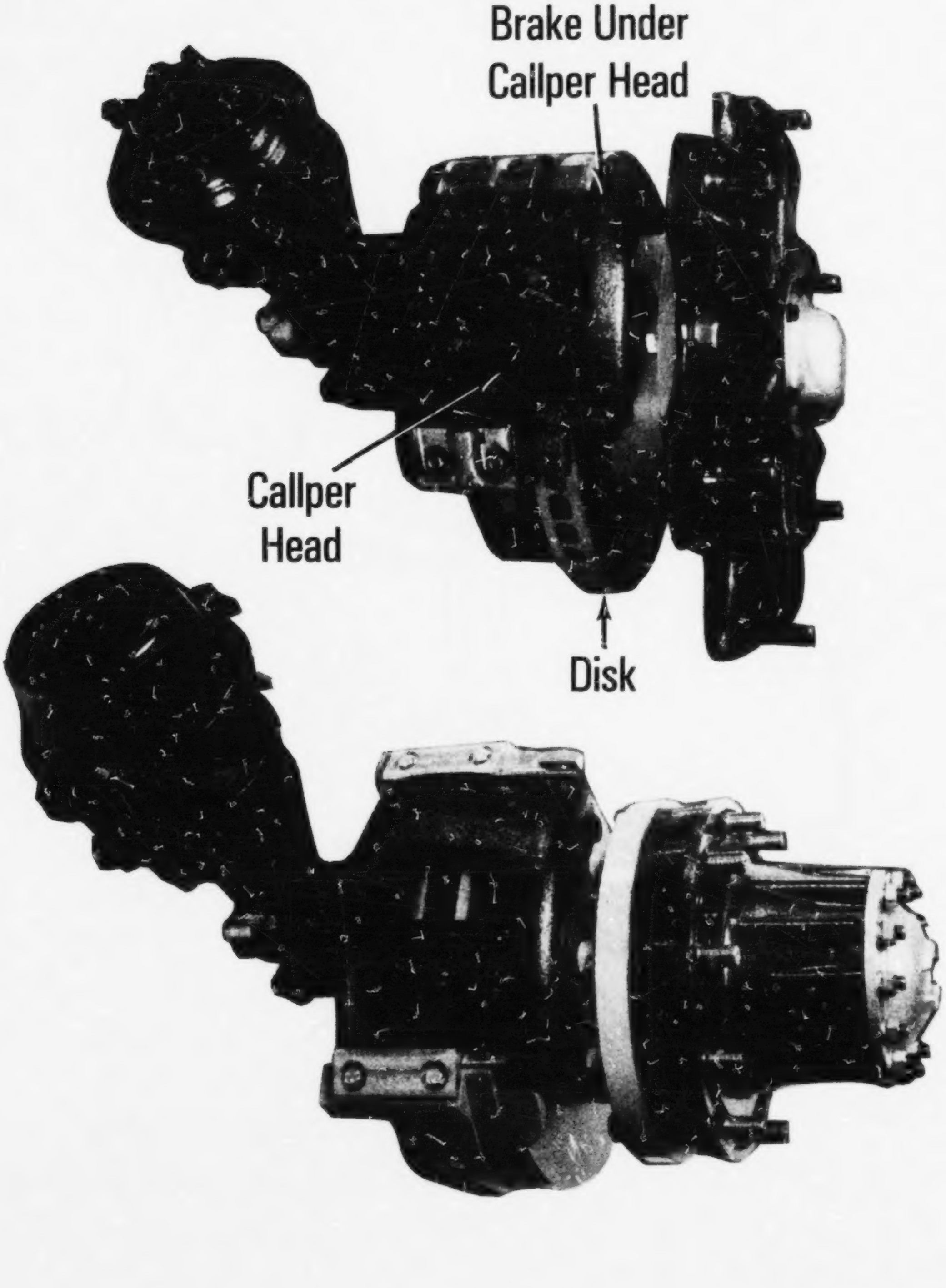


Stud, Nut and Washer Installed (Spring Compressed)

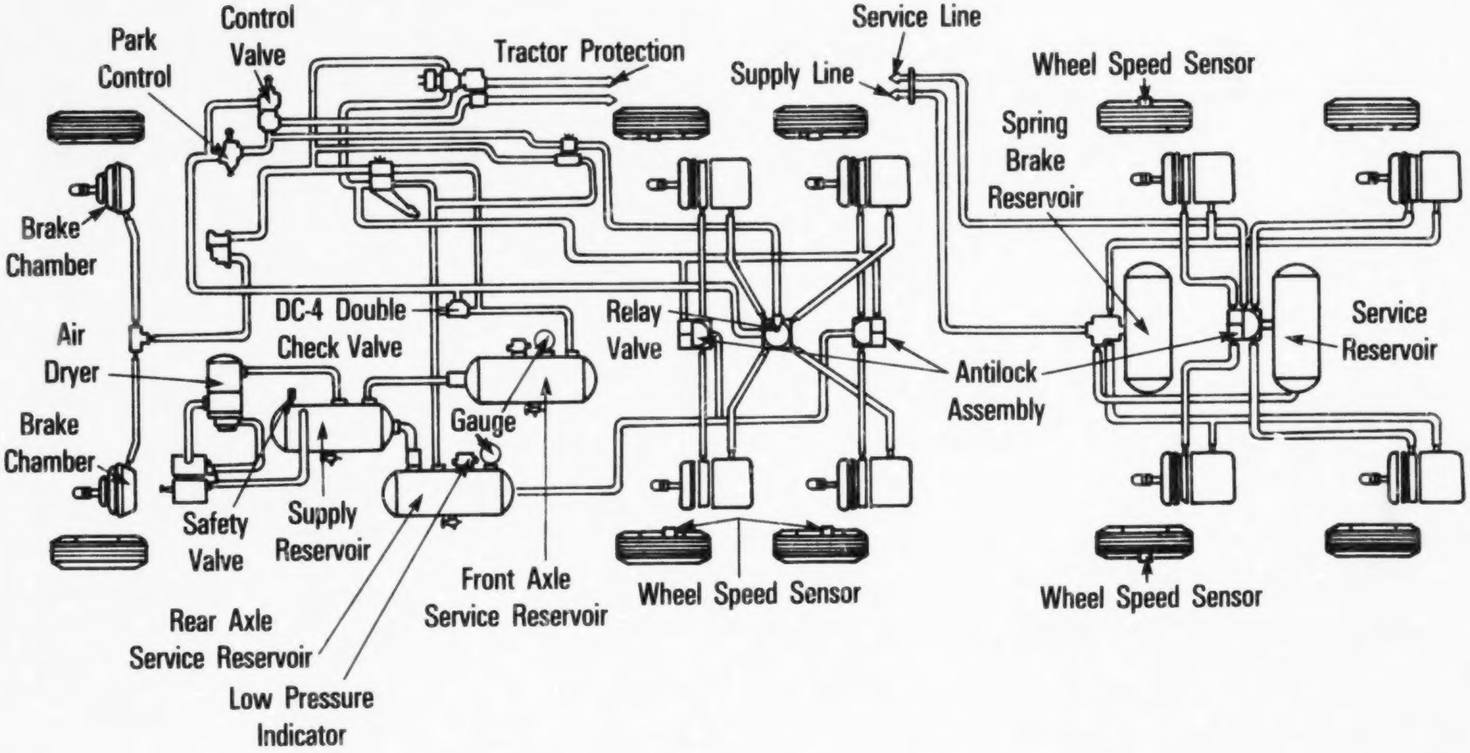
Storage Location for Stud, Nut and Washer

Visual 9.45

Disk Brake


Brake Under
Caliper Head
Caliper
Head
Disk

Typical F.M.V.S.S. 121 Dual Air Brake System


Park Control
Control Valve
Tractor Protection
Service Line
Supply Line
Wheel Speed Sensor
Spring Brake Reservoir
Brake Chamber
DC-4 Double Check Valve
Relay Valve
Antilock Assembly
Service Reservoir
Air Dryer
Gauge
Brake Chamber
Safety Valve
Supply Reservoir
Front Axle Service Reservoir
Wheel Speed Sensor
Wheel Speed Sensor
Rear Axle Service Reservoir
Low Pressure Indicator

Truck Tractor System

Trailer System

Visual 9.47

Total Stopping Distance

Speed Miles Per Hour	= Feet Per Second	Preception and Reaction Distance	PLUS	"Air Brake Lag" Distance	PLUS	Actual Braking Distance	Equals	Total Stopping Distance
15	22.0	34	+	6	+	13	=	53 Feet
20	29.3	44	+	8	+	22	=	74 Feet
25	36.6	54	+	10	+	35	=	99 Feet
30	44.0	66	+	12	+	50	=	128 Feet
40	58.6	88	+	16	+	89	=	193 Feet
50	73.2	110	+	20	+	139	=	269 Feet
55	80.6	120	+	22	+	169	=	311 Feet
60	88.0	132	+	24	+	201	=	357 Feet

Average Driver Perception Time =.75 Second   Average Driver Reaction Time=.75 Second

Total Driver Perception and Reaction Time=Distance Traveled in 1.5 Seconds

Average "Brake Lag" Distance (Time for Air to Pass Through a System in Good Working Order)=The Distance Traveled in .27 Seconds

Actual Braking Distance (After Shoes Make Contact With the Drums and Tires Are on Good, Dry Pavement) the Coefficient of Friction=.6 Deceleration Rate at 19.3 Feet Per Second/Per Second Average

Distances Based Upon a Fully Loaded Tractor-Trailer

Note: These Are Best Possible Stopping Distances—Under "Average" Conditions These Distances Will Increase Considerably

Speed Retarders

(Auxiliary Brakes)

Four Basic Types

1. Exhaust Brakes
   - Williams Air Controls – "Blue Ox"
   - Mercedes Benz Trucks – "Exhaust Brake"
2. Engine Brakes
   - Jacobs Manufacturing Company – "Jake Brake"
   - Mack Trucks – "Dynatard"
3. Hydraulic Retarders
   - Caterpillar Tractor Company – "Cat Brakesaver"
   - Detroit Diesel Allison's – "Allison Integrated Retarder"
4. Electric Retarders
   - Jacobs Manufacturing Company – "Jaker Brake"
   - Francoise Thelma Company – "Thelma Retarder"

10. WHEELS, BEARINGS, RIMS, AND TIRES (50 minutes)

Introduction

This topic is designed to provide students with a basic knowledge of

- The functions of wheel bearings
  - Their components
  - Methods of lubrication
  - Inspection
- Various types of wheel assemblies
  - Their components
  - Methods of assembly
  - Hazards
- Basic tire types
  - Construction methods
  - Handling characteristics
  - Causes for failure

Purpose

To transmit engine power to road surface in safe and efficient manner, permitting the driver to control speed and direction of vehicle travel

Wheel Bearings

Visual 10.1 View of Wheel Bearings Mounted to Axle Assembly

View of Wheel Bearings Mounted to Axle Assembly

Function
- Support weight of vehicle and load
- Reduce friction between axle shafts and wheel hubs
  - Friction
    - Produces heat, increasing axle shaft wear
    - Reduces fuel economy
    - Damages wheel and steering system components

Location

- Front Tractor Axle/Trailer Axles
  - Located on axle shaft
  - Both inner and outer bearings

- Rear Tractor Axles
  - Located on end of axle housing
  - Outer bearing only

Wear

- Front axle/trailer axles
  - Frequent replacement due to
    - Turning forces
    - Curbstrikes
    - Collisions with road debris
- Rear tractor axle
  - Infrequent replacement

Rotation

- Front axle/trailer axles
  - Bearings rotate on axle
  - Axle does not turn
- Rear tractor axles
  - Bearings rotate in axle housing
  - Axle rotates

Visual 10.2 View of Bearing Components

Bearing Components

Cup

- Press fitted into hub
- Provides smooth surface for bearings to rotate

Cage

- Houses individual bearings
- Holds bearings in position between cup and cone
- Tapered

Cone

- Pressed inside bearing cage
- Fits between cage and axle shaft
- Provides smooth surface for bearing

Bearings

- Rotate between cup and cone
- Held in position by nut on end of axle shaft
- Presses bearing cage and cone against cup

Bearing Play

- Deliberate looseness in bearing assembly
- Allows bearings to expand when hot without increasing friction

Bearing Damage

Caused By

Excessive Play

- Bearings assembled too loosely
- Bearings damage cup edge
- Cup fractures

Inadequate Play
- Bearings assembled too tightly
- Bearing assembly expands under heat
- Scales bearings

Contamination
- Dust, corrosives, etc.
- Pits bearings
- Damages cup
- Allows corrosion

Symptoms

Noise
- "Growling" when wheel is rotated
- Chattering when negotiating curves/turns

Vibration
- Steering wheel vibrates slightly
- Front end vibrates

Temperature
- Hub assembly hot to touch
- Lubricant leaking from hub assembly

Visual 10.3 Diagram of Oil Bath and Grease Pack Front Axle Bearing Assemblies

Bearing Lubrication

Two types
- Grease Packed
- Oil Bath

Grease Packed
- High viscosity lubricant
- Packed into hub assembly
- Grease cup on end of axle shaft
  - Retains grease in hub
  - Prevents leakage
  - Found on older trucks

Advantages
- Ease of maintenance
- Ease of installation
- Close tolerances not required

Disadvantages
- Lubricant crystalizes or liquifies under high heat conditions
- Can transport contaminants to bearings
- Viscosity increases significantly at low temperatures
- Lubricant condition not readily inspected
- High viscosity retards lubrication in close tolerance portions of bearing assembly

Oil Bath
- Low visocity lubricant
- Bearing assembly bathed in lubricant
- Seals prevent leakage
- Oil retained in reservoir
- Seals held in place by wire rings
- Installed on new trucks
- Advantages
  - Lubricant less affected by temperature changes
  - Contaminates settle to bottom of reservoir
  - Lubricant level and condition inspectable without removing hub assembly
  - Lubricant reaches close tolerance areas of bearing assembly
  - Improved distribution of lubricant on bearing surfaces
  - Reduced wear on axle surfaces
  - More accurate adjustment of bearing play
- Disadvantages
  - Installation and maintenance more complex
  - Leakage possible
  - Lubricant loss occurs rapidly with seal failure

WHEEL ASSEMBLIES

Function

- Provide secure mounting surface for tire
- Transmit road shocks to suspension system
- Distribute weight of vehicle and load across axles

General Types

Visual 10.4 Diagram of Spoke and Disk Wheels

Spoke
- Spokes radiate from hub to wheel rim
- No wheel, as such
  - Spokes replace wheel
- Hub detachable from rim components

Disk
- Hub part of axle
- Wheel and rim components one unit

SPOKE WHEEL COMPONENTS

Visual 10.5 Components of Spoke Wheel with One-piece Rim

Hub
- Houses axle bearing cups and axle shaft
- Connects remainder of wheel assembly to axle

Serves as grease reservoir for grease-packed bearing systems

Constructed of

- Cast steel
- Cast aluminum alloy

Contains mounting studs for attaching rim located at ends of spokes

Visual 10.6 Profile View of Assembly (Spoke End, Stud, Lug Nut, and Rim Clamp)

Lug Nut Assembly

Consists of

- Stud
- Rim clamp
- Lug nut

Stud

Protrudes from end of hub spoke

Rim Clamp

Holds rim to spoke facing

Lug Nut

Binds rim clamp to rim

Rim

- Contains flanges for holding tubes/tires
- Mounting point for tubes/tires
- Connects tire assembly to hub
- One or more components
  - One-piece rims
  - Two-piece rims
  - Three-piece rims

Visual 10.7 One-Piece Rim

One-Piece Rim

Rim base, inner, and outer rim flanges are integral

Visual 10.8 Two-Piece Rim (Disassembled with Split and Continuous Side Rings)

Two-Piece Rim

- Inner rim flange integral with rim base
- Outer rim flange detachable
  - Referred to as side ring or side flange

Side Ring

- Fits in gutter on outer edge of rim base
- May be split or continuous
  - Split--facilitates installation and removal
  - Continuous--less subject to damage during installation or improper installation

Visual 10.9 Three-Piece Rim (Disassembled with Side Ring and Lock-Ring)

- Three-Piece
  - Inner rim flange integral with rim base
  - Outer rim flange detachable
    - Held in place with lock-ring
  - Lock-ring split

Disk Wheel Components

Visual 10.10 Disk Wheel with One-Piece Rim

- Hub
  - Not part of disc wheel assembly
    - Bolted to axle assembly
    - Disc wheel bolts to hub
  - Constructed of:
    - Cast steel
    - Cast aluminum alloy
- Wheel
  - Circular steel dish
    - May be flat or curved
  - Constructed of forged/stamped steel
  - Connects rim to hub assembly
  - Contains mounting holes for hub studs
  - Mounted to hub with lug nuts
- Rim
  - Integral with wheel
  - Contains flanges for holding tubes/tires
  - One or more components
    - One-piece rims/wheels
    - Two-piece rims/wheels

Visual 10.11 Two-Piece Disk Wheel (Vertically Split Rim Base)

Two Types

- Vertically Split Rim Base
  - Rim flanges detachable
    - Both flanges integral with each half of split rim base
  - Inner flange seated in groove on outer portion of rim base
  - Air pressure
    - Exerts outward force on tire side walls
    - Locks rim halves together

Side Ring

- Inner rim flange integral with rim base
- Rim base not split vertically
- Outer rim flange detachable
  - Functions as side ring
  - May be split or continuous

Single-Piece/Multi-Piece Rims

- Single-piece rims
  - Tire/tube is worked onto rim with tools
  - Required for tubeless tires
  - Optional for tube-type tires

  - Advantages
    - Rim less prone to failure from
      - Improper assembly
        - When mounting rim to hub
        - When replacing tires
      - Improper mounting
        - To hub
        - To spoke
      - Damage to components during assembly or disassembly
    - Fewer parts
    - Provides most secure mounting surface for tires

  - Disadvantages
    - Tire/tube mounting and dismounting difficult
      - Can result in damage to tire bead or wall

- Multi-Piece Rims
  - Tube tires only
  - Tubeless tires cannot be mounted on multi-piece rims
  - Rim is assembled inside tire/tube

  - Advantages
    - Ease of tire assembly/disassembly
    - Less likely to damage tire/tube components in assembly

  - Disadvantages
    - Assembly method complicated
      - Greater number of components
      - Close tolerances
      - Components easily damaged
    - Damage to rim components can cause tire/rim failure
    - Assembly/disassembly hazardous
      - Rim components can part under pressure of inflation
    - Mounting requirements more critical
    - More frequent in-route inspection requirements
    - Improper assembly or mounting can result in
      - Increased tire wear
      - Increased bearing/axle wear

Spoke/Disk Wheel Assemblies

- Spoke Wheel Assemblies
  - Advantages
    - Improved air flow over brake drums
    - Less expensive than disk
    - Ease of mounting/dismounting tire/rim combinations
      - For maintenance
      - For tire repairs
  - Disadvantages
    - Improper mounting of rim to spoke can result in:
      - Increased tire wear
      - Stress on steering system components
      - Increased axle/bearing wear
      - Failure of hub/rim assembly
      - Difficult to align/adjust
    - To prevent rim failure, lug nuts must be torqued:
      - To specified loadings
      - In specified sequence
- Disc Wheel Assemblies
  - Advantages
    - Ease of mounting wheel assembly to--axle, hub
    - Simplicity of mounting requirements
      - Entire wheel assembly is bolted to axle in one step
    - Fewer parts, resulting in:
      - Reduced maintenance requirements
      - Greater durability
    - Truer running, which reduces:
      - Tire wear
      - Steering system wear
      - Less rim/wheel stress
  - Disadvantages
    - Higher initial cost
    - Less airflow around brake components
    - Mounting/dismounting more cumbersome

Visual 10.12 Diagram of Rear Duals Detailing Location of Spacers

Spacers

- Required on dual wheel assemblies to:
  - Prevent rear wheels from touching
  - Increase air flow around wheels
  - Maintain proper distance between dual tire assemblies

Visual 10.13 Diagram of Torque Sequence for Spoke Wheel

Torqueing Wheels

- Reasons for:
  - Prevent damage to lug nuts, clamps, studs
  - Insure uniform tightening of wheel assembly
  - Maintain proper wheel/tire alignment

Visual 10.13 Diagram of Torque Sequence for Spoke Wheel

Torqueing Wheels

- Reasons for
  - Prevent damage to lug nuts, clamps, studs
  - Insure uniform tightening of wheel assembly
  - Maintain proper wheel/tire alignment
- Overtorqueing Indicated by
  - Cracked lug nuts
  - Cracks radiating from stud mounting holes
- Undertorqueing Indicated by
  - Elongation of stud mounting holes
  - Abrasion of studs

TIRES

Visual 10.14 Diagram of Tubeless and Tube Type Tires and Their Components

General Types

- Tube Type
  - Inner tube serves as air reservoir
    - Fits inside tire
    - Between tire and rim
  - Inner tube separated from rim components by rubber flap
    - Flap protects tube from chafing and pinching between rim components
  - Inflation of inner tube holds tire in place against rim flanges
  - Valve stem part of tube assembly
  - Can be used on single or multi-piece rims
- Tubeless Types
  - Tire body serves as air reservoir
  - No tube or flap required
  - Air pressure forces tire bead to seat against rim flange
  - Special tubeless rims required
    - Rim flanges differ from tube type
    - Valve stem mounts in rim
  - Mounted on single-piece rims only

Visual 10.15 Diagram of Tire with Components Exposed

Major Components

- Beads
  - Steel bands which encircle tire's inner circumference
    - On both sides of tire
    - Provide rigidity at tire's point of contact with rim flanges
    - Prohibit distortion of tire

Plies

- Wrap tire from bead to bead
- Serve as foundation for tire tread
- May be more than one layer.

EXAMPLES:

    - Two-ply
    - Four-ply
- Number of plies determines load-bearing capacity of tire
    - More plies greater load-bearing capacity
- Constructed of various materials
    - Steel
    - Rayon
    - Nylon
    - Fiberglass

Belts

- Located between plies and tire tread
- Run circumferentially around tires
- Restrict tread movement and constrict body plies
- Constructed of same materials as plies
- Serve as mounting point for tread

Sidewall

- Outer covering of tire extending from bead to tread edge
- Provides rigidity to tire assembly
- Protects plies from road damage
- Holds tread in place on belts/plies

Visual 10.16 Schematic of Tread Types

Tread

- Surrounds tire belts/plies
- Bound to tire assembly by sidewalls
- Grooved or shaped to provide traction

Ribs

- Grooves in tire tread running parallel to sidewalls
- Can be used at all axle positions
- Best for steering axle application
    - Provides maximum steering capability
    - Good skid resistance

Lugs

- Deep grooves in tire shoulders running perpendicular to tire sidewall
- May be in combination with ribs
- Best for drive axle positions
    - Resistant to wear
    - Provide maximum traction
    - Greater mileage at drive axle locations than ribbed type

Special Service

- Deeply lugged tires
- No ribs
- Suitable for high-traction situations only
  - Mud
  - Snow
- Poor wear at highway speeds or long distances

Tire Design

Visual 10.17 Bias-Belted Tire (Construction)

Radial

- Body plies run perpendicular to tire beads
- Greater wearability due to
  - Lower temperature buildup
  - Decreased rolling resistance
- Greater traction in turns due to sidewall flexibility which
  - Does not lift tread edge when cornering
  - Prohibits tread from collapsing from cornering pressures
- Improved fuel economy because of reduced rolling resistance
- Relatively thin sidewalls easily damaged
- Require special tubes for tube-type tires designated by "R" in tube size code
- Require special flaps
- Easily damaged by underinflation

Bias

- Body plies run at angle to tire beads
- Wear rate higher than radials
- Greater sidewall strength
- Less traction due to
  - Tread pick-up during turns
  - Tread collapse
- Hold tread rigidly in place
- Overinflation causes tread to pick-up at edges

Bias Belted

- Belts encircle plies
- Located between plies and tread body
- Greater wearability than bias
- Belts improve tread stability
  - Reduce tread motion during road contact

Mixing Tires

- Can reduce wear rate
- Differences in traction can
  - Induce skids
  - Change handling characteristics

- Never mix tires
  - On same axle
  - On tandem-drive axle combinations
- Use all of one type on nonsteering axles

Tire/Tube Designation

- "R" in sizing code denotes radial
- No code denotes bias or bias-belted

Tire Size

- First number denotes the width in inches of the tire measured at the outside edge of sidewall at widest point
- Second number denotes the tire diameter at the tire bead

Visual 10.18 Tire Inflation

Tire Under and Over Inflation Effects

- Inflated to manufacturers specifications
  - Inflated to proper pressure only when cold
- Air pressure increases as tire heats from road friction--approximately 15 lbs psi over normal

Underinflation

- Does not improve ride quality
- Increases heat build up, reducing
  - Tire wear rate
  - Traction
- Can cause tire fire

Overinflation

- Reduces ride quality
- Increases stress and load on axle and steering system components
- Reduces traction by lifting tread edges from road surface
- Increases wear on center portion of tread

Visual 10.19 Dual Wheels

Duals Wheels

- Tires mounted in duals must be same size
- Must be spaced properly with wheel spacer ring

Sizing

- Size differences create overloading on smaller tire
  - Increases wear rate
  - Heat build up
- Differential damage occurs on tandem drive tractors if
  - Diameter of tires on one tandem smaller than diameter of tires on other

- Maximum difference in tire diameter--1/2 inch for tires 9 inches wide or wider
- Maximum difference in tire circumference--3/4 inch

Spacing

- Spacing between rear duals required to prevent contact between tires
- Space rings used to maintain tire spacing
  - Fit over axle
  - Between inner and outer duals

Inadequate Spacing

- Tires "kiss" during rotation or cornering
- Produces heat which can build enough to cause fire

Excess spacing

- Increased drag from air resistance
- Tires "scuff" during cornering from offtracking

Reconditioned Tires

Two Types

- Recapped
- Regrooved

Can be legally mounted on any axle except front steering axles

Recaps

- Remaining tread is shaved from tire
- New tread is bonded to old tire carcass
- Wear rates equal or exceed original tread if maintained properly
- Carcass can be recapped two or three times if in good condition
- Tread can separate from carcass if
  - Tire carcass is defective or damaged
  - Tire overheats
- All tire types recappable
  - Radial
  - Bias
  - Bias belted

Regrooved

- Existing tread removed
- New tread cut into tire body
- Can be done only on specially designed tires

Visual 10.20 Diagram of Tire with Where to Measure Tread Depth

Measured by inserting tread-depth gauge into major tread grooves--the minimum requirements are

- Front Axle
  - 4/32 of an inch when measured at two adjacent major tread grooves at three equally spaced points around tire
- Other Axles
  - 2/32 of an inch when measured at two adjacent major tread grooves at three equally spaced points around tire

Locating and Recognizing Problems

Inspection

- During vehicle inspection, it is vital that drivers check for any defects in wheel bearings, wheel assemblies, and tires
- Wheel Assemblies
  - Rims and rings that are mismatched, bent, sprung or cracked
  - Disc wheels with elongated bolt holes or cracks between the hand holds or stud holes or both
  - Cast spoke wheels or spoke type that are cracked
  - Wheel bolts, nuts, clamps that are loose, broken, missing, or mismatched
  - Any disk or spoke type wheel or rim assembly with a welded repair
  - Any leaking or otherwise defective wheel bearing
- Tire
  - Any tire that has a bump, bulge or knot apparently related to tread or sidewall separation
  - Any tread separation from the carcass of the tire itself, especially those that expose fabric
  - Any tire that has cuts through more than the outer most layer, especially if the textile lowers underneath can be seen through the cut
  - Any tire that is flat or has an audible air leak
  - Any tire in a dual set that is mounted or inflated so that it comes in contact or may come in contact with its mate
  - Any steering axle tire that is obviously recapped
- Drivers must check all tires with an air pressure gauge for proper inflation
  - Striking tires to determine inflation pressure only tells whether there is air in the tire or not
  - It does not tell whether the tire has been inflated to the manufacturers' recommended inflation pressure
  - It is essential for both tire longevity and/or maximum vehicle fuel economy that tires be run at precisely the right pressure

NOTE: Remember that improperly inflated tires can easily catch fire. Once tires are on fire they are virtually impossible to extinguish.

Operation

During operation, drivers must
- Stay alert for unusual sounds or vibrations indicating
  - Wheel bearing failure or impending failure
  - A problem with a wheel assembly
  - A flat tire
- At the first indication of such a problem, the drivers shall
  - Immediately pull off road
  - Locate the problem
  - Take corrective action

Post-Trip

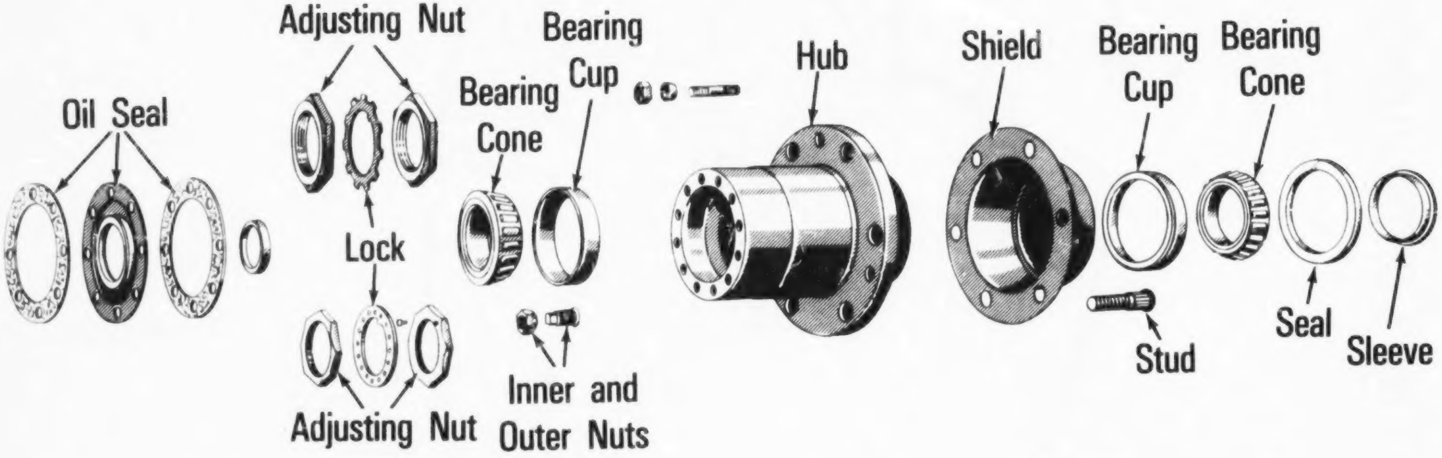
Drivers must promptly report any known or suspected defects

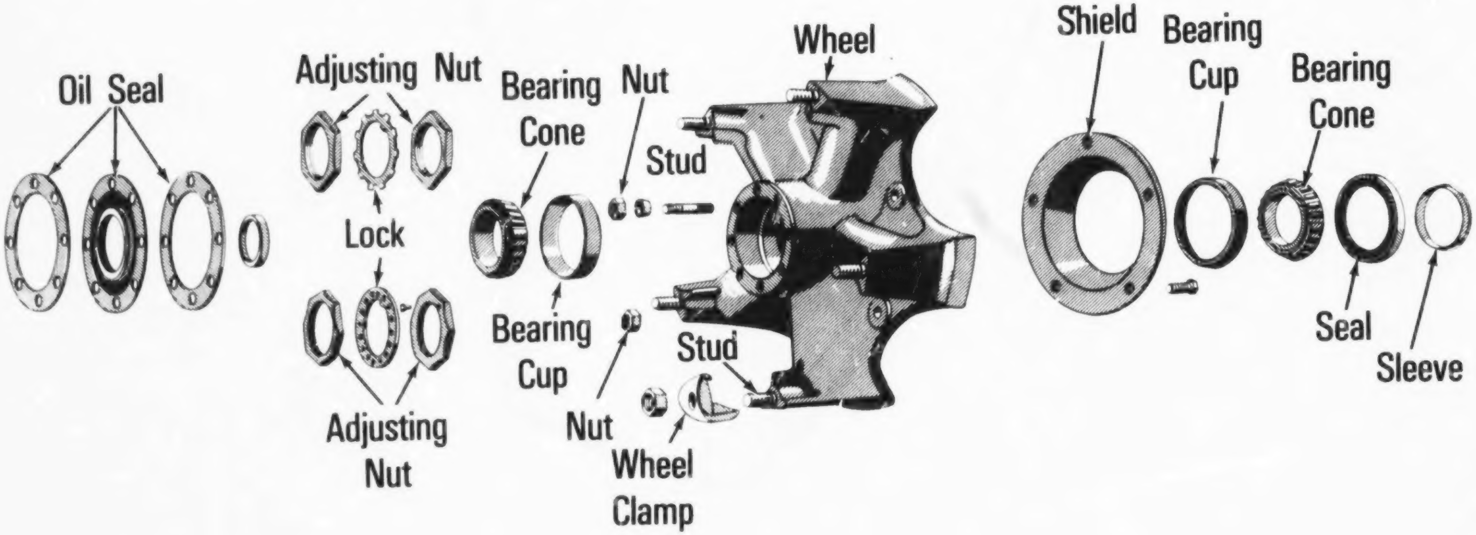
Recap

- Tires and wheels are all that is between vehicle and the road
- It is essential that they be carefully and continuously inspected pretrip, enroute and post-trip
- Various types of tires and various types of wheel assemblies have differing operating characteristics
  - What is safe on one is not safe on the other
  - It is up to the driver to understand the characteristics of the tires and wheel assemblies on the vehicles he drives
    - To fully understand conditions which are safe versus conditions which are not
    - To inspect these assemblies to ensure the safety of the vehicle as well as that of other road users
- While enroute, the driver must be constantly alert for any sign of malfunction in the wheel assembly and tires of his vehicle
- It is the driver's responsibility to recognize the high cost of today's tires and to take steps to preserve and extend the useful working life of these tires

Visual 10.1

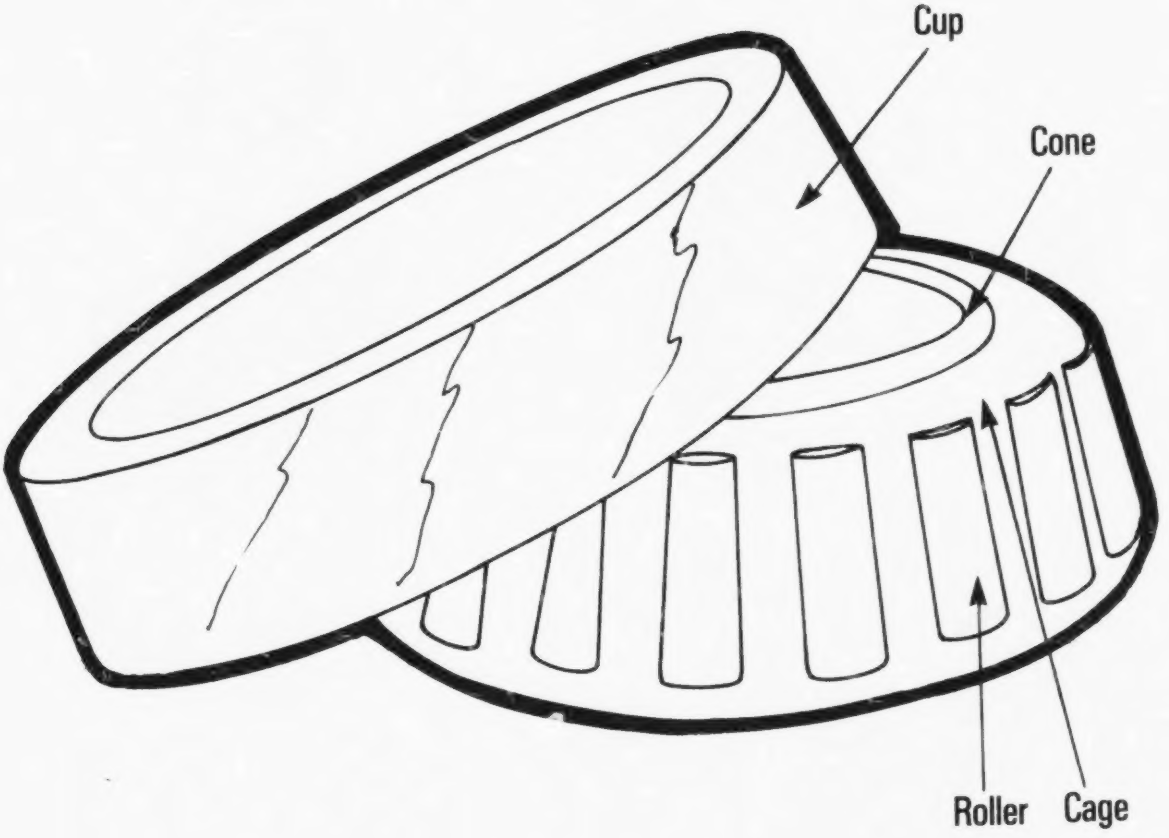
Wheels Bearings


Oil Seal
Adjusting Nut
Lock
Adjusting Nut
Bearing Cone
Bearing Cup
Inner and Outer Nuts
Hub
Shield
Bearing Cup
Stud
Bearing Cone
Seal
Sleeve


Oil Seal
Adjusting Nut
Lock
Adjusting Nut
Bearing Cone
Bearing Cup
Nut
Stud
Wheel
Stud
Nut
Wheel Clamp
Shield
Bearing Cup
Bearing Cone
Seal
Sleeve

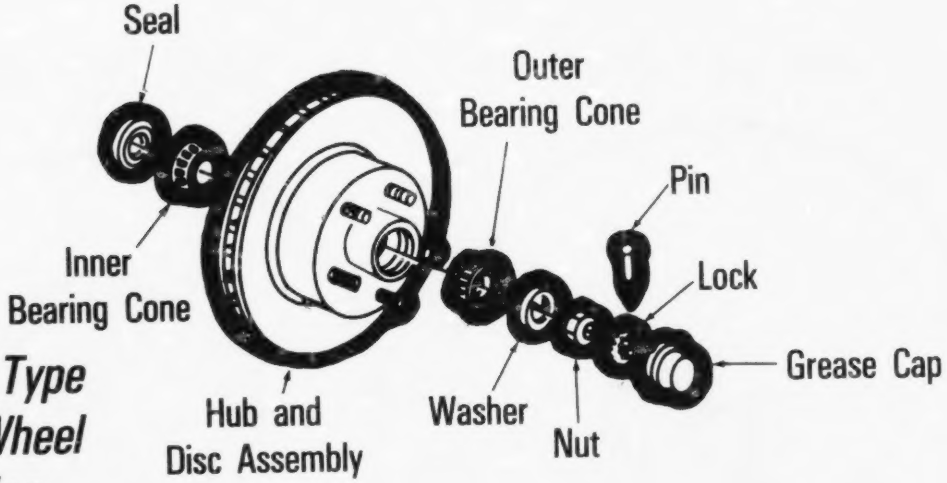
Visual 10.2

Wheel Bearing Components

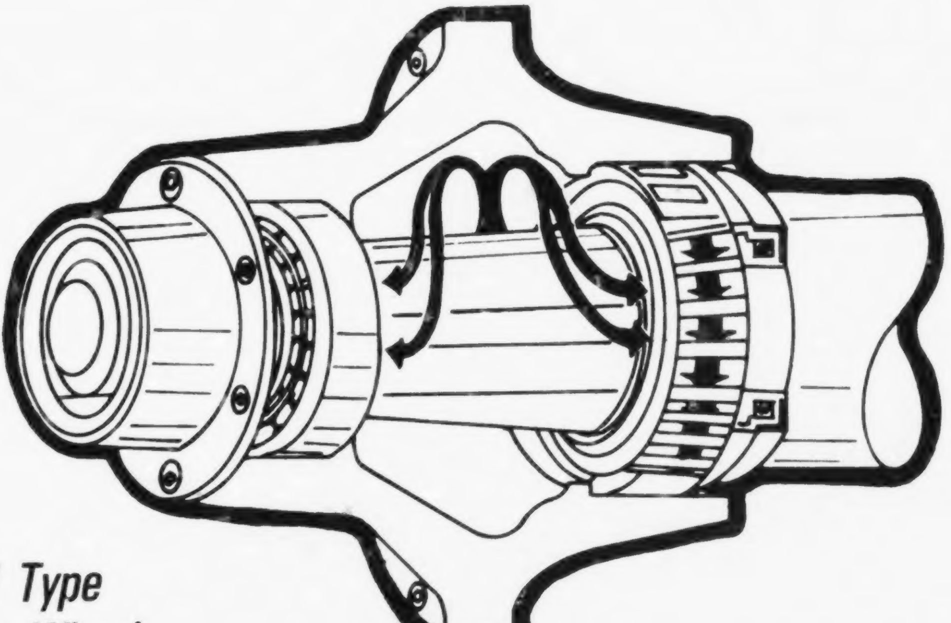

Cup
Cone
Roller
Cage

Visual 10.3

Grease and Oil Lubricated Bearings


Seal
Outer Bearing Cone
Pin
Lock
Inner Bearing Cone
Grease Cap
Hub and Disc Assembly
Washer
Nut

Grease Type Front Wheel Bearing

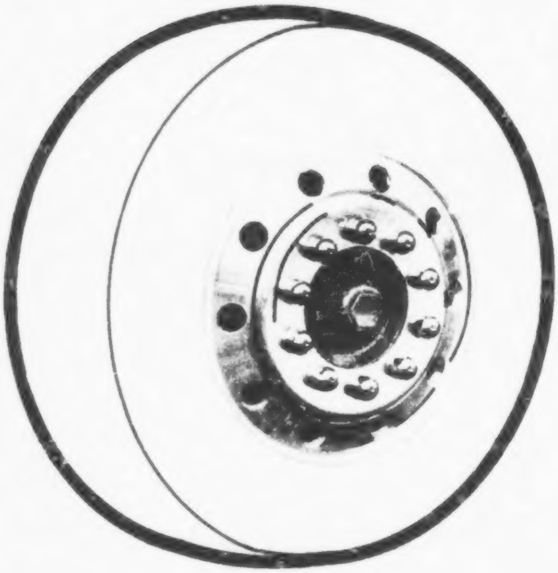


Oil Type Front Wheel Bearing

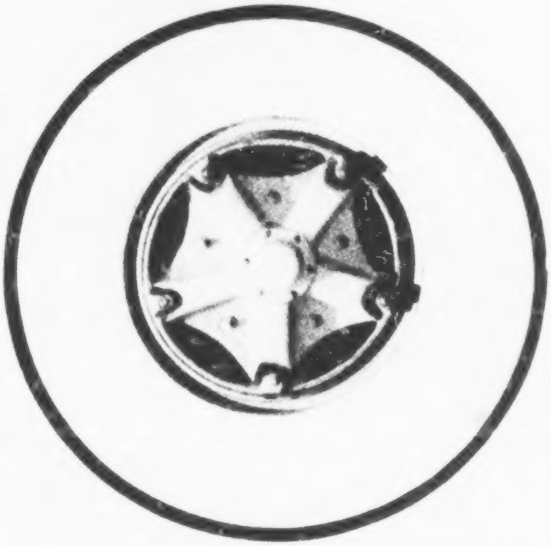
Arrows Indicate Oil Flow

Visual 10.4

Disk Type Wheel

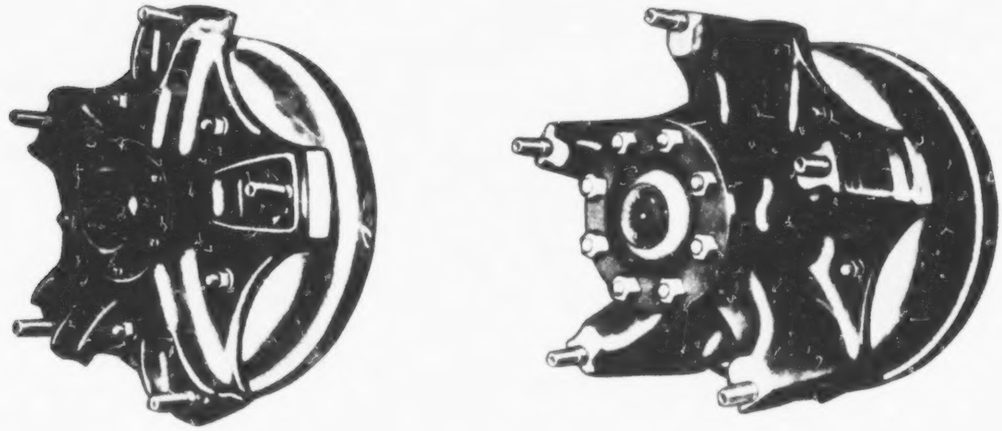


Spoke Type Wheel



Visual 10.5

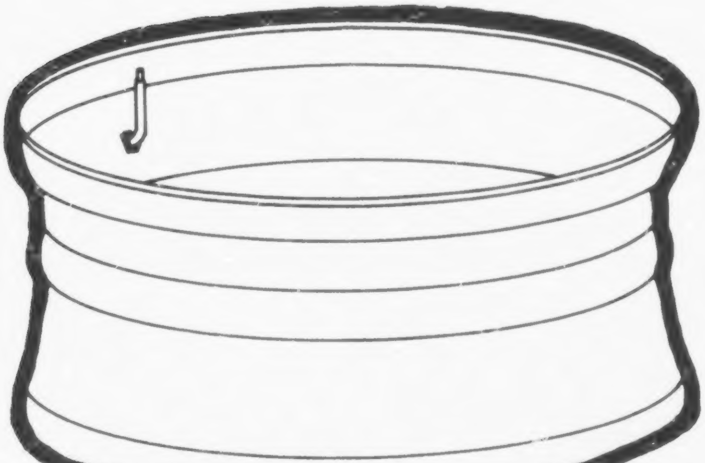
Spoke Wheel With One Piece Rim



Front

Rear

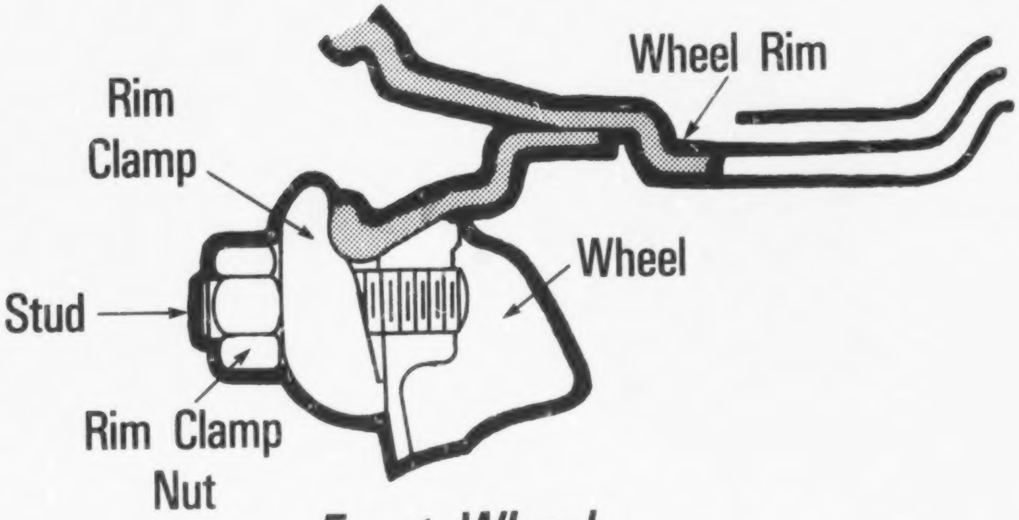
Cast Spoke Wheels



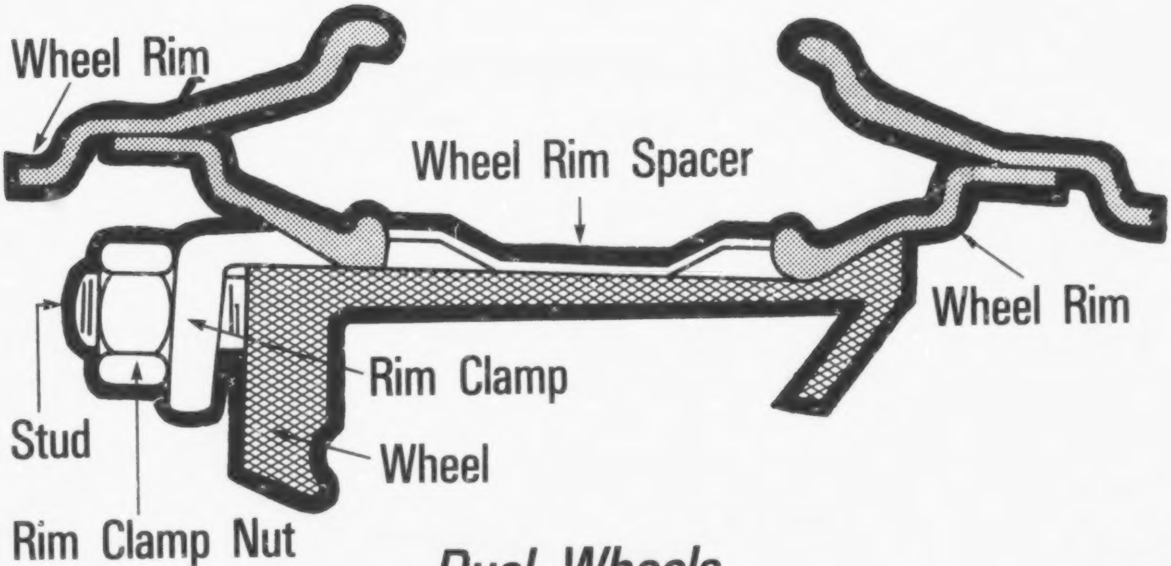
One-Piece Rim

Visual 10.6

Profile View of Assembly


Wheel Rim
Rim Clamp
Wheel
Stud
Rim Clamp Nut

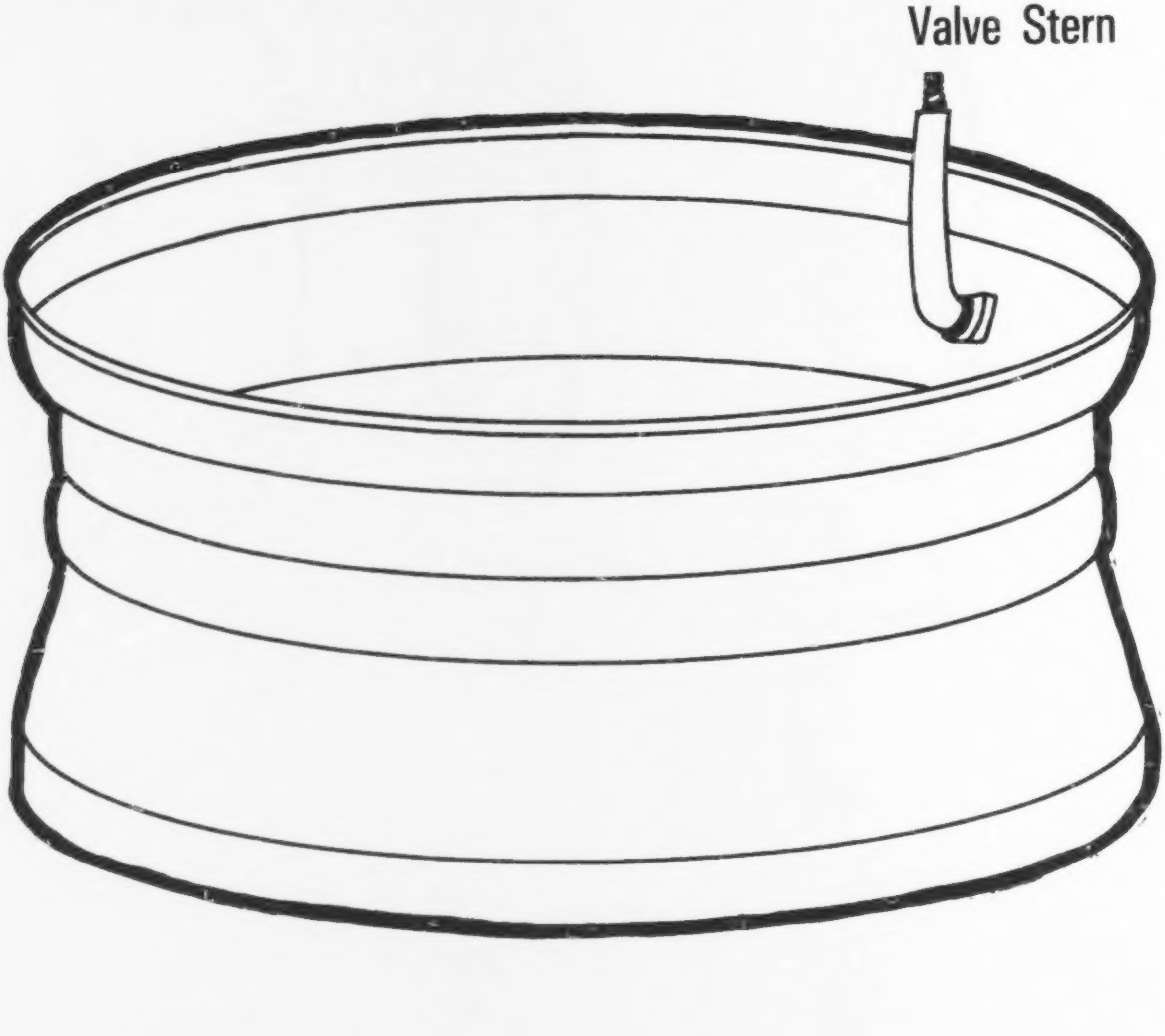
Front Wheel


Wheel Rim
Wheel Rim Spacer
Wheel Rim
Rim Clamp
Stud
Wheel
Rim Clamp Nut

Dual Wheels

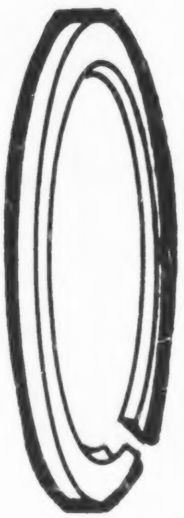
Visual 10.7

One-Piece Rim

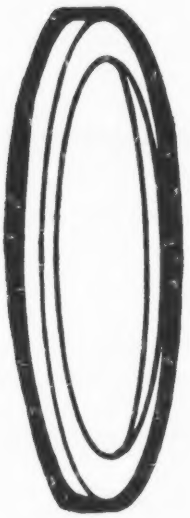

Valve Stern

Visual 10.8

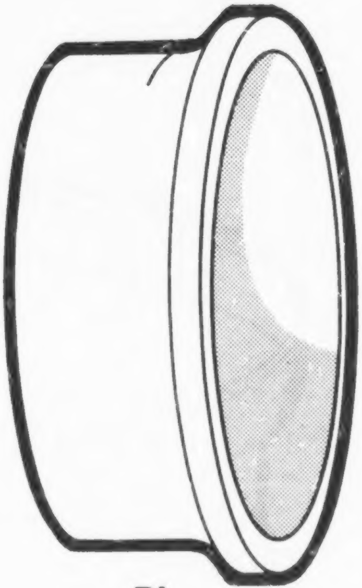
Two-Piece Rim



Split Side Ring



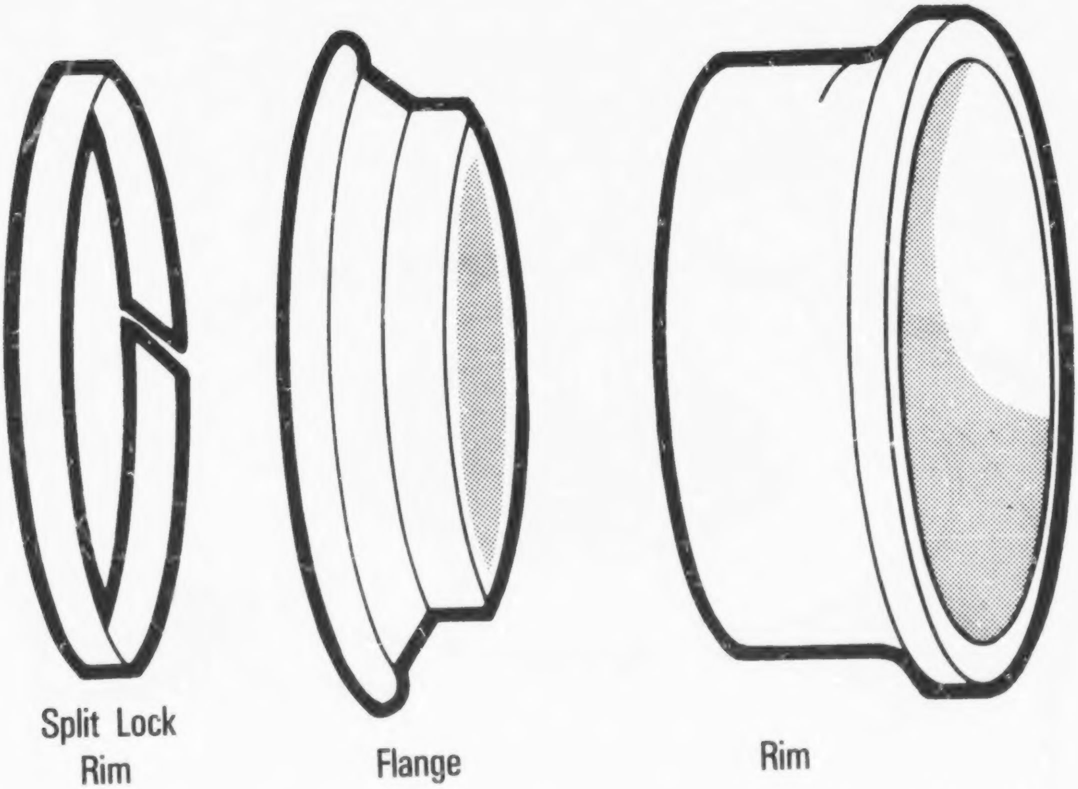
Continuous Side Ring

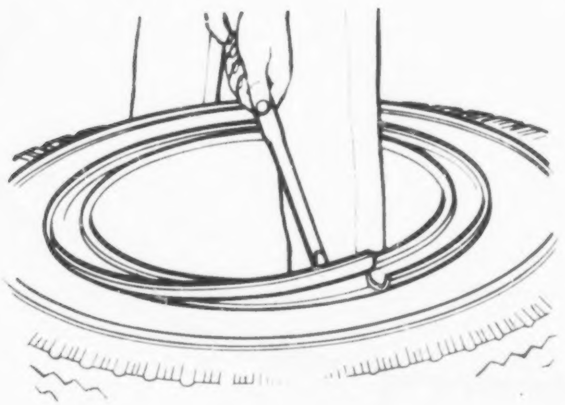


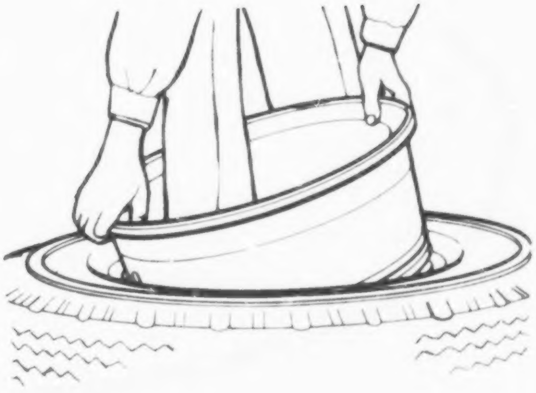
Rim

Visual 10.9

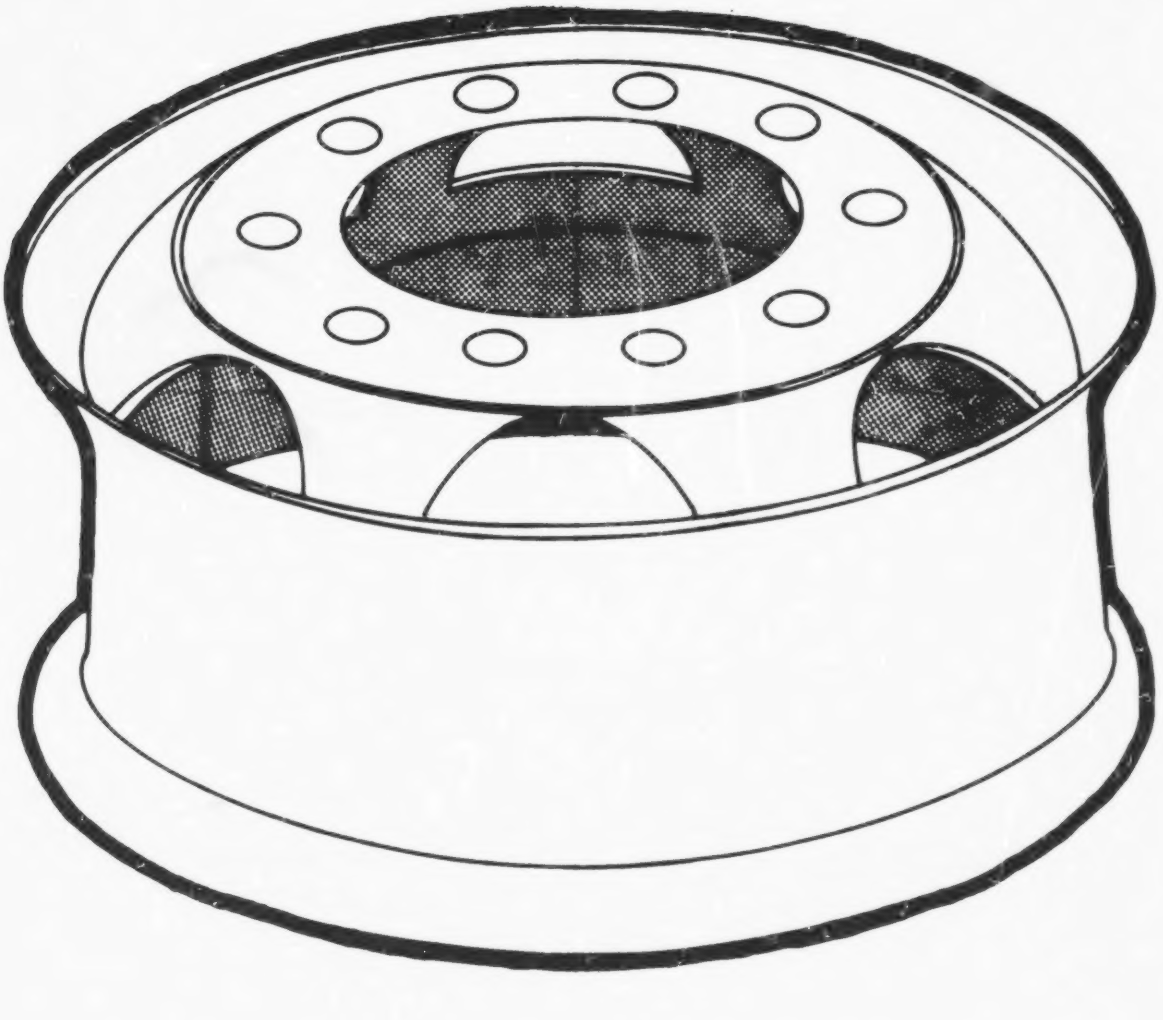
Three Piece Rim


Split Lock Rim
Flange
Rim



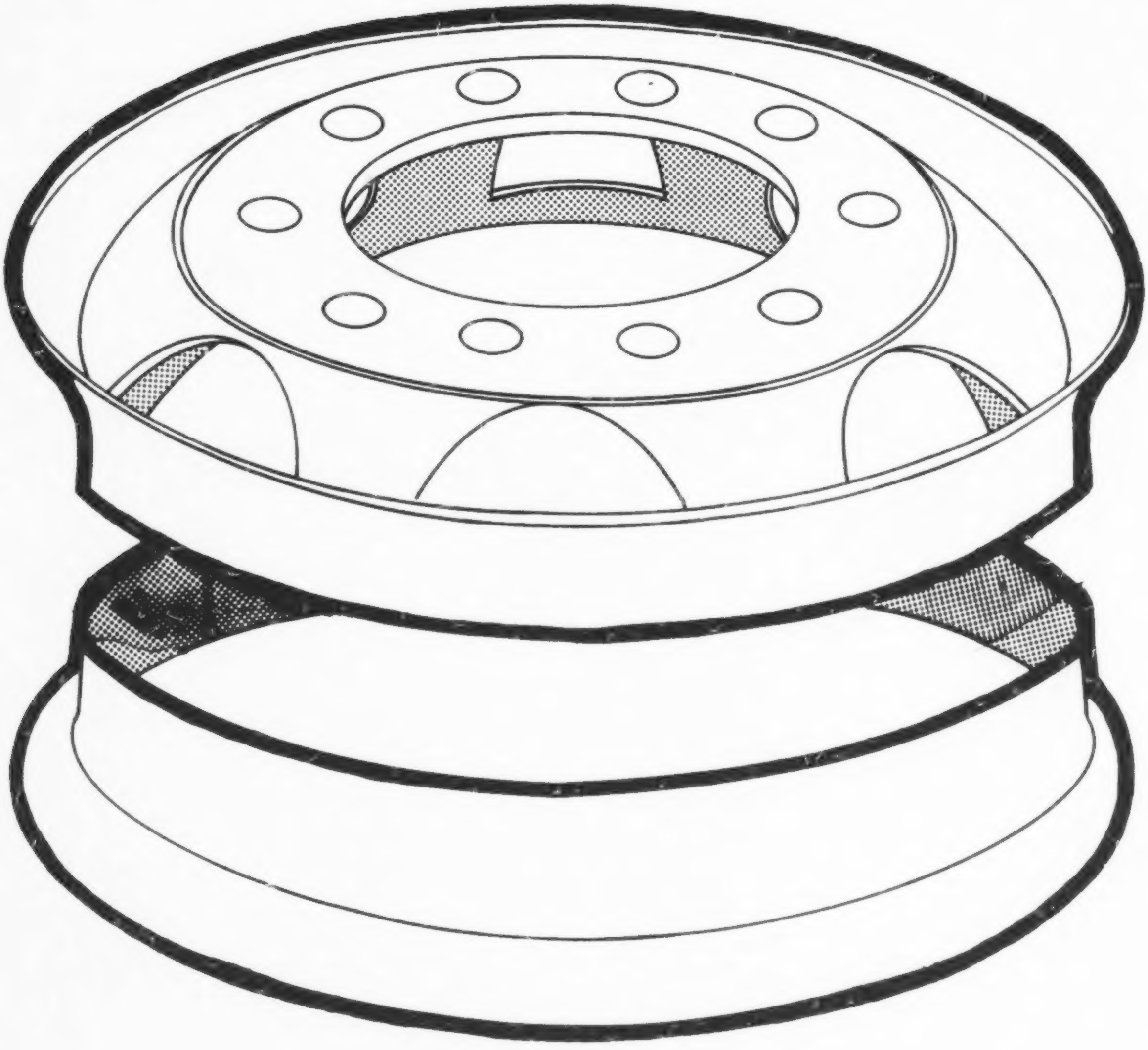


Disk Wheel With One Piece Rim

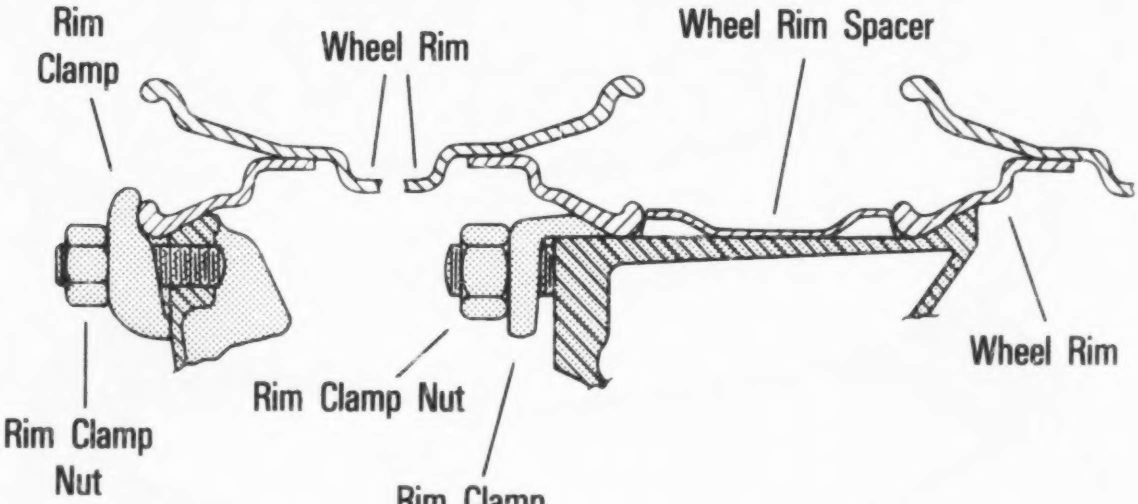


Visual 10.11

Two Piece Disk Wheel

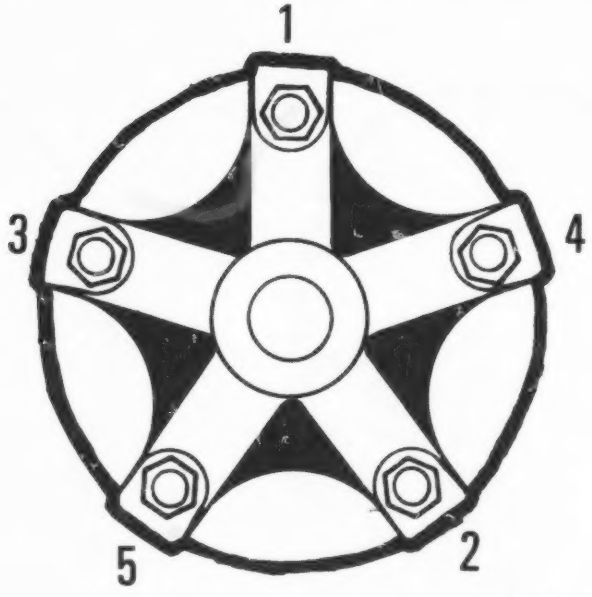


Dual Wheel Spacers

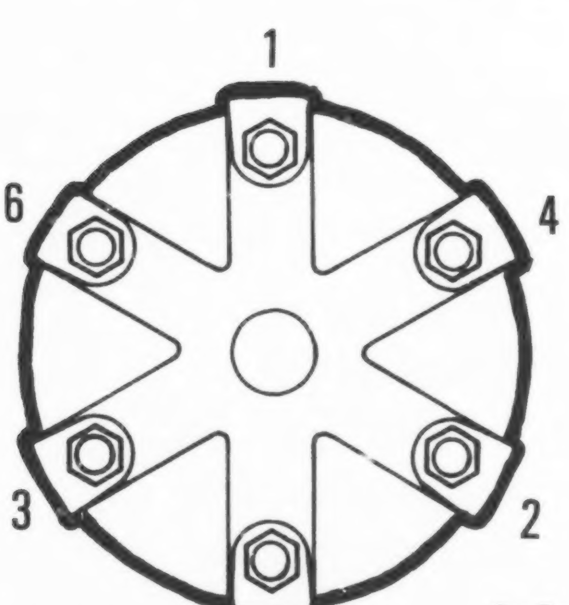

Rim Clamp
Wheel Rim
Wheel Rim Spacer
Rim Clamp Nut
Rim Clamp Nut
Rim Clamp
Wheel Rim

Visual 10.13

Torque Sequence for Cast Spoke Wheels



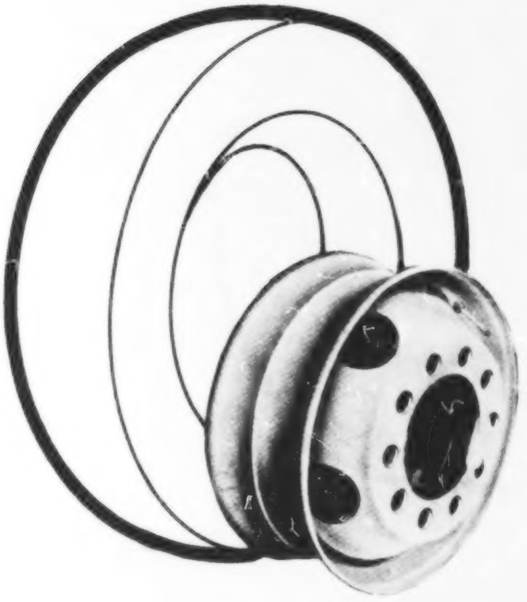
5 Spoke Type



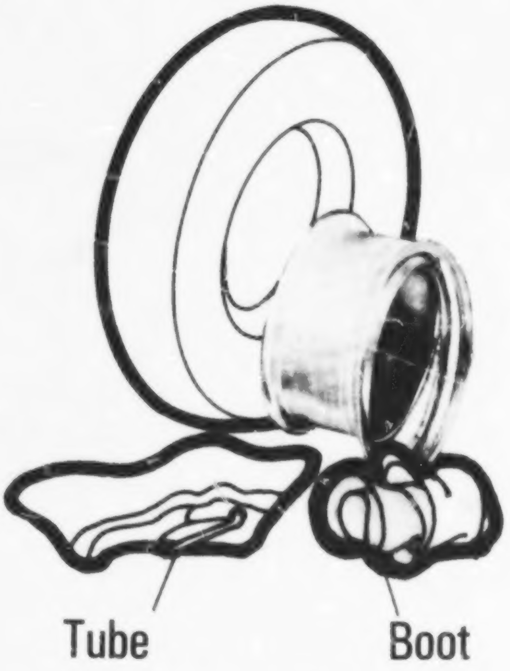
6 Spoke Type

Visual 10.14

Tubeless Versus Tube Tires



Tubeless

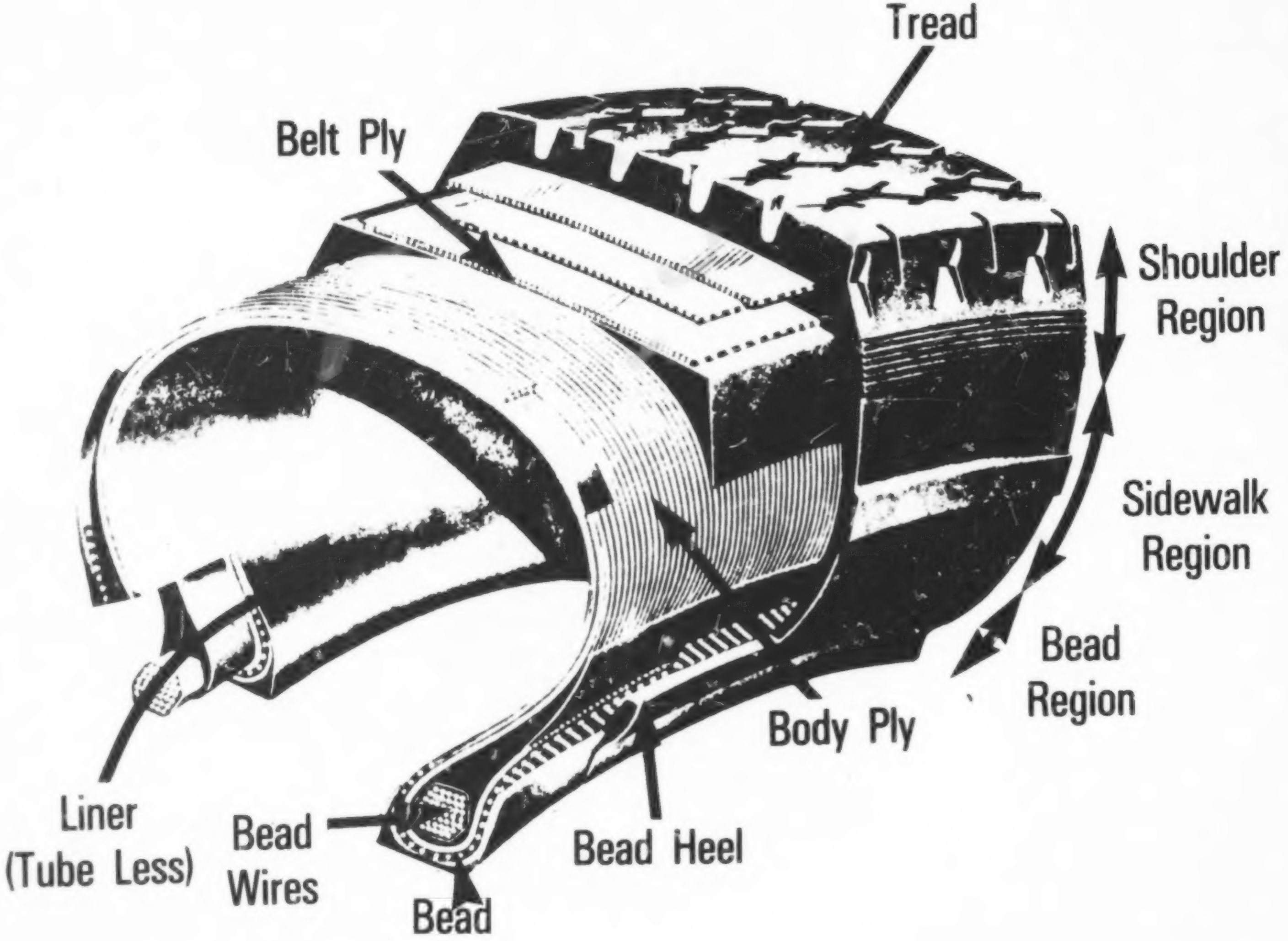


Tube-Type

Advantages of Tubeless Tires:

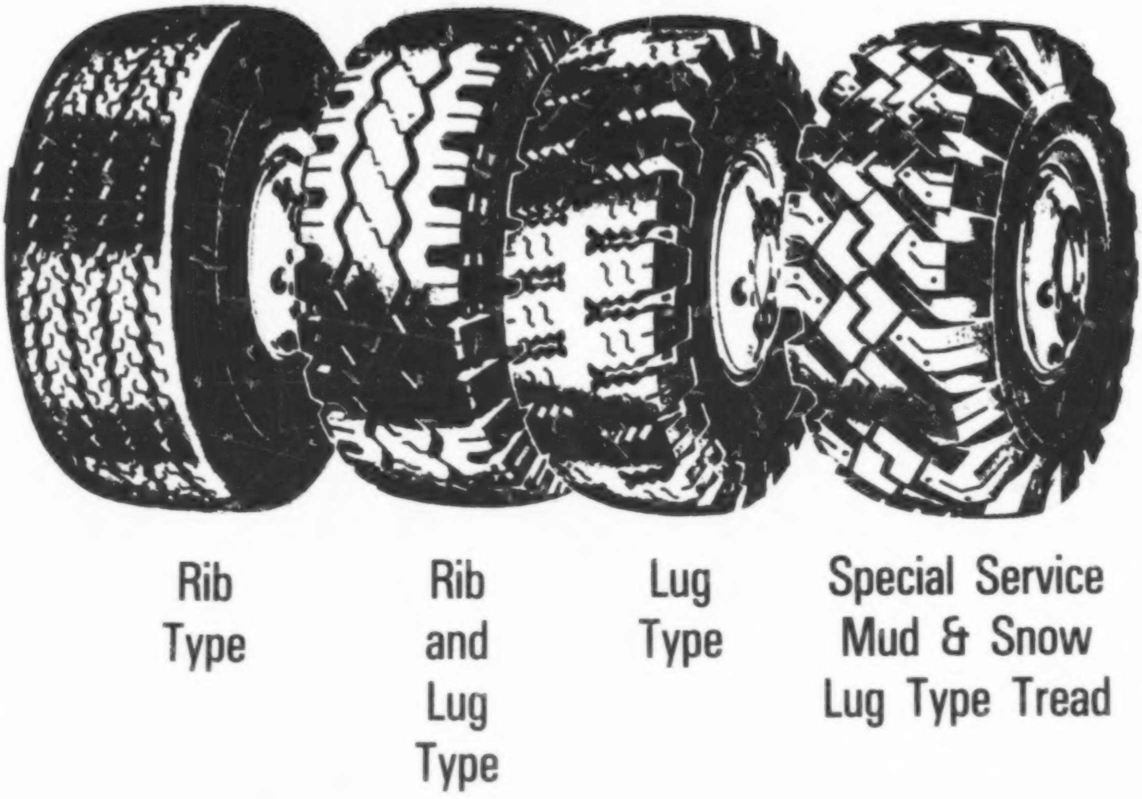
1. Fewer Parts
2. Less Weight
3. Fewer Road Delays
4. Less Labor Costs
5. Cooler Running
6. Safer to Mount and Dismount

Tire Components


Tread
Belt Ply
Shoulder Region
Sidewalk Region
Bead Region
Body Ply
Liner (Tube Less)
Bead Wires
Bead Heel
Bead

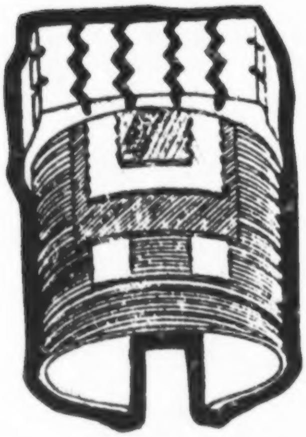
Visual 10.16

Tire Tread Types

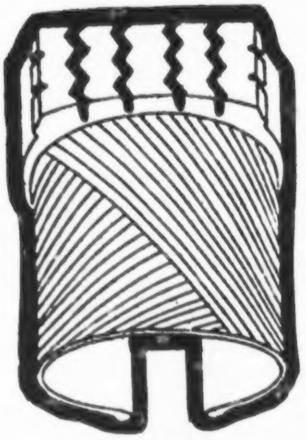

Rib Type
Rib and Lug Type
Lug Type
Special Service Mud & Snow Lug Type Tread

Visual 10.17

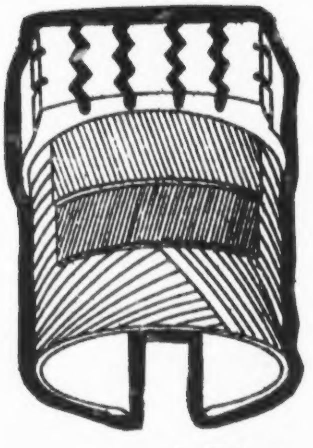
Tire Construction



Radial



Bias



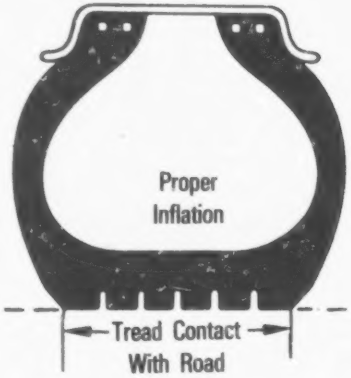
Belted Bias

Radial–Body Ply Cords Run Perpendicular Across Tread, Belt Plys Run Circumferentially Around Tire Under Tread.

Bias–Body Ply Cords Run Diagonally Across Tread.

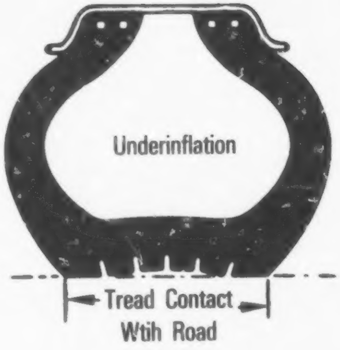
Belted Bias–Body Ply Cords Run Diagonally Across Tread. Belt Plys Run Circumferentially Around Tire Under Tread.

Tire Inflation


Proper Inflation
Tread Contact With Road

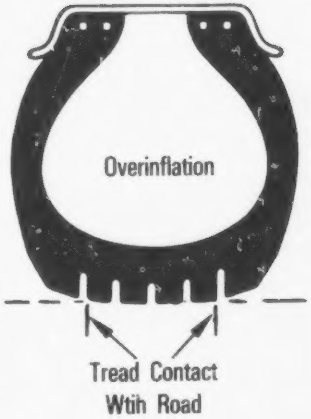
Proper Inflation

Full Contact With Road


Underinflation
Tread Contact Wtih Road

Underinflation

Causes Irregular Wear,
Abnormal Tire Deflection,
Excessive Heat Build-Up.

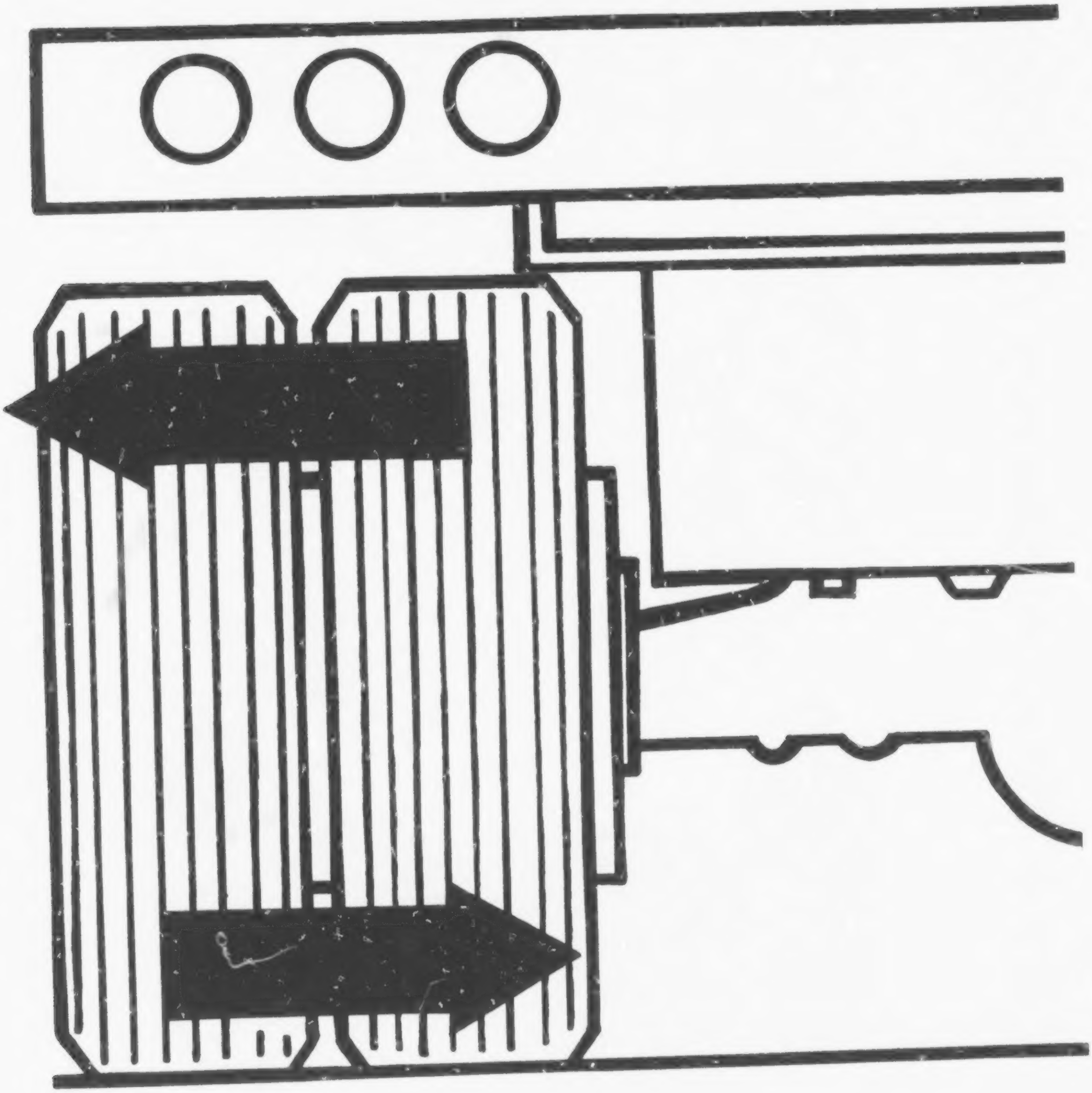

Overinflation
Tread Contact Wtih Road

Overinflation

Tires Run Hard, Causes
Irregular Wear.

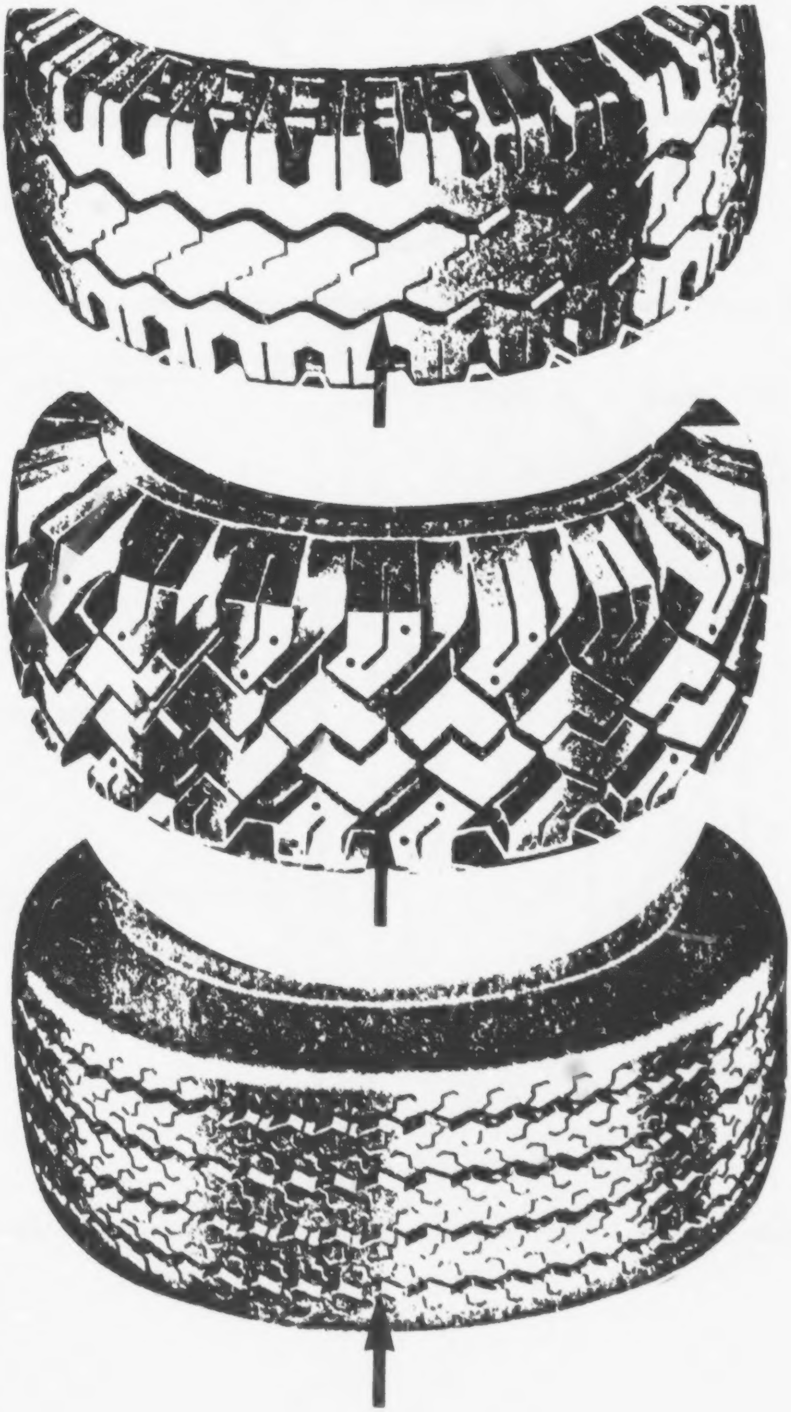
Visual 10.19

Dual Wheels



Visual 10.20

Here is Where to Measure Tread Depth



11. STEERING SYSTEMS (20 minutes)

Introduction

This topic is designed to provide students with a basic knowledge of

- Major components of steering systems
- General types of steering systems
- Steering system adjustments required to
  - Prolong tire life
  - Minimize wear and stress on system components
  - Maintain steering control

Purpose

To permit driver to control vehicle's direction of travel by changing the angle of the front tires of the tractor to the road surface

Basic Steering System

System Consists of

- Steering wheel
- Steering shaft
- Steering gears
- Pitman arm
- Drag Link
- Steering arms
  - Upper
  - Lower
- Steering knuckle
- Tie rod

Operation

- Rotation of steering wheel is transmitted to steering gears through steering shaft
- Circular motion of steering gear is transferred to linear motion through action of Pitman arm
- Action of Pitman arm moves upper steering arm through connecting drag link
- Movement of upper steering arm causes left front steering knuckle to turn in response to steering wheel rotation
- Movement of left steering knuckle is transmitted to right knuckle by the tie rod
- Tie rod is connected to lower right and left steering arms

Components and Functions

Visual 11.1 Steering System and Components

Steering Wheel

- Used by driver to turn front wheels of tractor
- Differing sizes
  - Small Sizes
    - Sensitive steering
    - More effort required to turn steering wheel
  - Large Sizes
    - Reduced steering sensitivity
    - Less effort required to turn steering wheel
- Connected to steering shaft with
  - Pressed fitting
  - Lock nut
    - Wheel puller required to remove
- Adjustable as to
  - Length--by telescoping action
  - Angle--by manipulating tilt adjustment

Steering Shaft

- Transfers driver's steering input to rest of steering system
- Constructed of two or more steel tubes connected by "U" joints
- Stiffness in turning action of steering wheel caused by
  - Looseness In
    - "U" joints
    - Excess steering lash

Visual 11.2 Schematic of Steering Gear and Pitman Arm

Steering Gears

- Attached to end of steering shaft at opposite end from steering wheel
- Housed inside of steering box to protect gears from damage by
  - Road debris
  - Corrosive action
- Converts turning motion of steering wheel into linear motion
- Gears mechanically increase power of driver's steering effort
- Stiffness in gearing action caused by
  - Lubricant
    - Worn out
    - Inadequate amount
  - Improper Lash (slack in steering wheel)
    - Insufficient lash causing gears to jam
    - Too much lash causing gears to mesh loosely

Pitman Arm

- Attached to shaft on one side of steering box
- Driven by steering gears
- Transfers steering action to front wheels of tractor

Drag Link

- Connects Pitman arm to upper steering arm
- Length is adjustable
- Connecting joints require lubrication
- Looseness in attachment points can cause
  - Front end vibration resulting in
    - Damage to other steering system components
    - Binding in steering action
    - Excessive tire wear

Steering Arms

- Two Types
  - Upper
    - Attached to upper half of steering knuckle
    - May be
      - Cast as part of steering knuckle
      - Bolted to steering knuckle
    - Connecting link between drag link and steering knuckle
    - Located on left side steering knuckle only
  - Lower
    - Attached to lower half of both left and right side steering knuckles
    - Connected to each other with tie rod

Visual 11.3 Steering Knuckle and Kingpin

Steering Knuckle

- Holds front wheel assemblies on front axle
- Attached to ends of front axle by
  - Kingpin
- Attached to Drag Link by
  - Upper steering arm
- Permits front wheels to swivel in response to turning of steering wheel

Visual 11.4 Tie Rods

Tie Rods

- Transfers steering motion of left front wheel to right front wheel
- Ends attached to lower steering arms by ball joints
  - Ball Joints
    - Require lubrication
    - Cannot be easily removed

Length of tie rod is adjustable
Damage to tie rod results in
    Steering system misalignment
    Excessive tire wear
    Failure of ball joints
    Loss of steering control

Visual 11.5 Center Point and Inclined Kingpins

Kingpins

Function

Attaches steering knuckles to front axle
Permits front wheels to swivel in response to turning of steering wheel
Held in place by lock nuts

Two Types

Center point--kingpin is perpendicular to axle
Inclined--kingpin is mounted at an angle to the axle

Characteristics of Kingpins

By stress on steering system components

Center Point
    Transfers load stress directly to axle and springs

Inclined
    Transfers load stress to most of other system components causing
        Increased wear rates
        Misalignment
By location

Center Point
    Kingpin is on centerline of wheel

Inclined
    Kingpin is between wheel and front axle
By ease of steering

Center Point
    Requires less driver effort to turn steering wheel
    Large turning radius
    Doesn't readily return to "straight ahead" steering position

Inclined
    Requires more driver effort to turn steering wheel
    Tighter turning radius
    Tendency to "center" wheels for straight-line tracking

By frequency
    Center point in more frequent use

Power Steering

- Manual--Driver's steering effort is transferred directly to front wheels by means of steering gears only
- Power assisted--driver's steering effort is hydraulicly "boosted" to reduce amount of effort required to turn steering wheel

  - Assist Methods
    - Air
    - Hydraulic fluid

Power Steering System Components

- Reservoir
  - Holds substance used to provide steering boost

  - Air Systems
    - Connected to air tank (brakes)

  - Fluid Systems
    - Separate fluid resevoir belt driven by engine and connected to fluid radiator for cooling

- Valve Body--governs amount of pressure applied to power steering cylinder
  - Activated by movement of steering gear

  - Location
    - Inside steering box
    - On side of steering box

- Power Steering Cylinder--exerts the mechanical force to provide power assist
  - Attached to frame and
    - Pitman arm or tie rod

Functioning of Power Steering System

- Reservoir--provides pressure to valve body through
  - Air pressure from air tanks
  - Fluid pump driven by engine for fluid systems

- Valve Body--transfers pressure to power steering cylinder in response to movement of steering wheel

- Power Steering Cylinder--"pushes" or "pulls" steering system in respsonse to pressure supplied by valve body

- Steering Wheel--controls valve body to control the amount of pressure exerted by power steering cylinder

- Loss of Boost
  - Evidenced by
    - Increased steering effort
    - Erratic steering control

- Can be caused by
    - Fluid leaks
    - Broken or loose drive belts
    - Inadequate fluid levels

Visual 11.6 Front Axle Toe-In

Alignment of Steering System

- Alignment of front tractor wheels affects
    - Tire wear patterns
    - Tire tread life
    - Ease of steering during
        - Cornering
        - Straight-line driving
    - Handling characteristics
    - Life of steering system components
- Proper wheel alignment maintained by adjusting
    - Toe
    - Camber
    - Caster

Toe--Distance between front edge of tires as compared to rear edge

- Toe-In
    - Front edge of tires closer than rear edge
- Toe-Out
    - Rear edge of tires closer than front edge
- Controls
    - Stability of steering in curves and straight-line driving
    - Tendency of front tires to "pull" away from one another
    - Wear on king pin bushings and tie rod ends
- Adjusted by
    - Altering length of tie rods
- Proper setting
    - Slight toe-in
    - Compensates for tendency of tires to pull out

Visual 11.7 Caster and Camber

Camber--Amount of "tilt" in wheels towards front axle

- Positive Camber
    - Distance between tires greater at top than at bottom
- Negative Camber
    - Distance between front tires greater at bottom than at top
- Controls
    - Tire wear under load
    - Turning radius
    - Angle of tire to road under load
- Adjusted by
    - Altering "tilt" of wheels
- Proper setting
    - Positive camber
    - Compensates for top of tires to pull inward under load

Caster--Location of centerline of wheels in relationship to front axle

- Positive Caster
  - Axle in front of centerline of wheel (kingpin tilted toward rear)
- Negative Caster
  - Axle in back of centerline of wheel (kingpin tilted toward front)
- Controls
  - Tendency of front wheels to return to straight ahead position
  - Effort required to turn steering wheel
  - Tire wear rates
- Adjusted by
  - Tilting the steering knuckle
- Proper setting
  - Positive caster
  - Causes axle to "pull" rather than "push" wheel
  - Reduces resistance somewhat
- Misalignment caused by
  - Striking curbs
  - Running over debris
  - Striking holes or cracks in pavement

Locating and Recognizing Problems

Operation

- During operation of motor vehicle, drivers must make sure that front axles are not overloaded beyond rated capacity
  - An overloaded front axle will be hard to steer
    - Very rapid tire wear will cause kingpin, bushing, and bearing wear
    - There is danger of bending of the axle beam
- Overloaded rear axles
  - Can cause the vehicle to sway and lean over dangerously
  - Can give a hard choppy ride
  - Can damage the chassis, body and cargo

- During operation, drivers should look for
  - Pulling to the right or to the left
  - Binding or deadspots in steering
  - Such items should cause vehicle to be pulled off the road and checked immediately

- Avoid striking debris on the highway
  - Going through chuckholes or potholes in the highway
  - Striking railroad tracks or crossing at too high a rate of speed
  - Such impacts can
    - Cause dangerous misalignment of front axles, front steering axles, settings, and of steering adjustment settings.
    - Cause rapid and premature tire wear
    - Make steering difficult
    - In the event of a skid may make it impossible to control the vehicle

Post-Trip

- Report any of the following:
  - Any steering problems noted enroute
  - If debris on highway was struck or potholes were struck
  - If excessive or premature tire wear is noted on steering axles, wheels
- These items should be brought promptly to the attention of the supervisor so that they may be corrected promptly to preclude the possibility of an accident

Recap

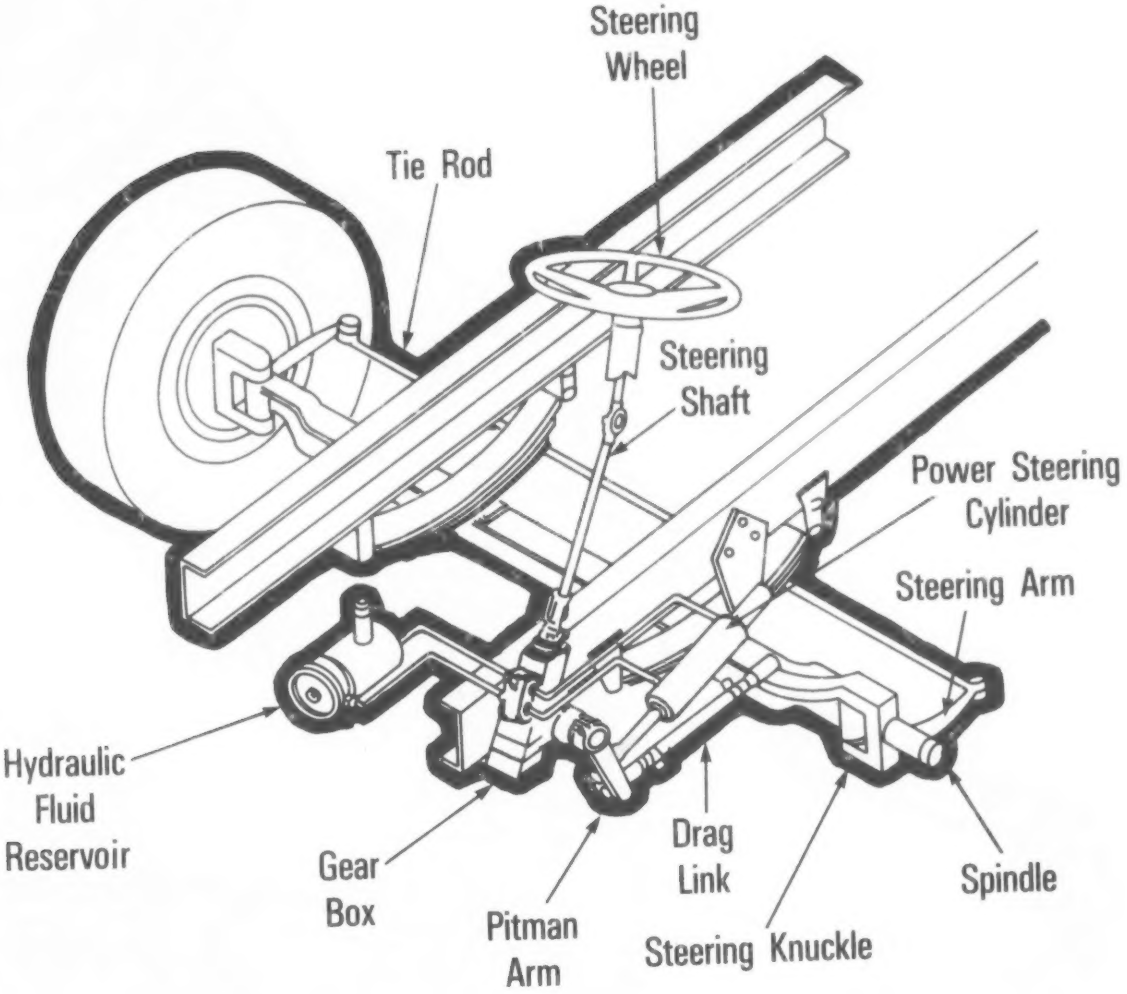
- The steering system
  - Frequently taken for granted
  - How it works and its proper function is often not understood

- It is important that the driver become completely familiar with the steering system on his vehicle and
  - Understand what its components are, their functions and when they are in need of adjustment
  - Be on the alert for any sign of system malfunction or any changes in the day-to-day function of the system
  - Promptly report any changes to supervisors
  - Report any striking of curbs, objects or holes in the roadway that could have thrown the various front steering adjustments out of proper adjustment

- During vehicle inspection it is vital that the driver check for any signs of visible damage to any of the steering system, components or parts
  - Look for evidence of bent, broken, or missing parts
  - Determine that the wheels can be turned from full left to full right without
    - Any interference from any parts of the vehicles
    - Any binding or crimping on the part of the mechanism itself
  - Steering wheel play should be approximately 10°
  - Steering gear column should not have any looseness and no parts or bushings or collars should be missing from it
  - The steering gear box must be adequately attached and not exhibit any missing bolts or movement during steering action
  - Check tie rod ends
  - Look for excessive wear and looseness
    - Joints should move freely but should have no end play except as allowed by compression of the tie rod end spring
  - Note the condition of sealing bolts, particularly on seal joints which do not have grease plugs or fittings
  - Check idle arm for worn bushing may be indicated by up and down play
  - Check the Pitman arm on the steering gear box for looseness.
    - No lack of up and down movement

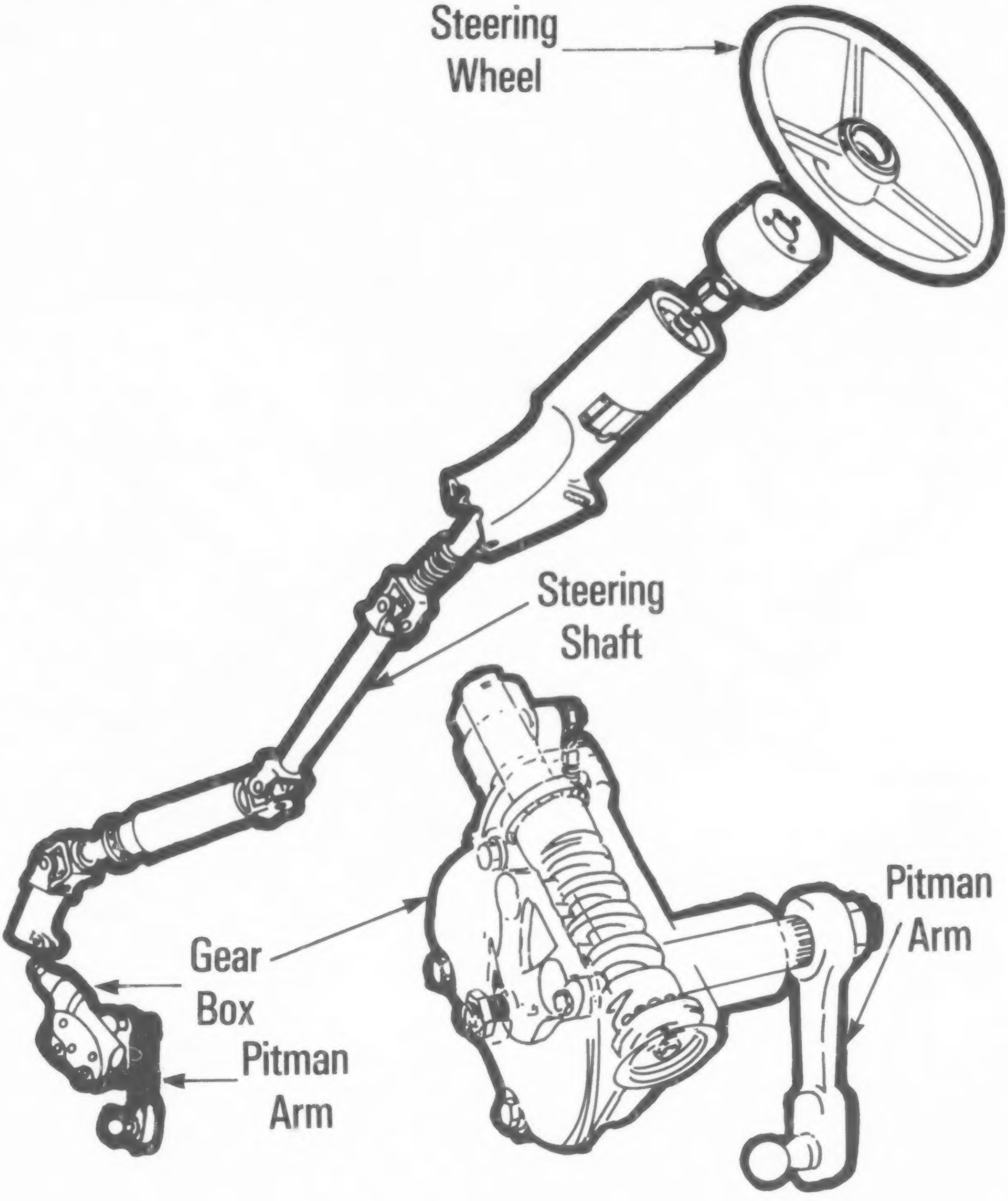
Visual 11.1

Steering System Components

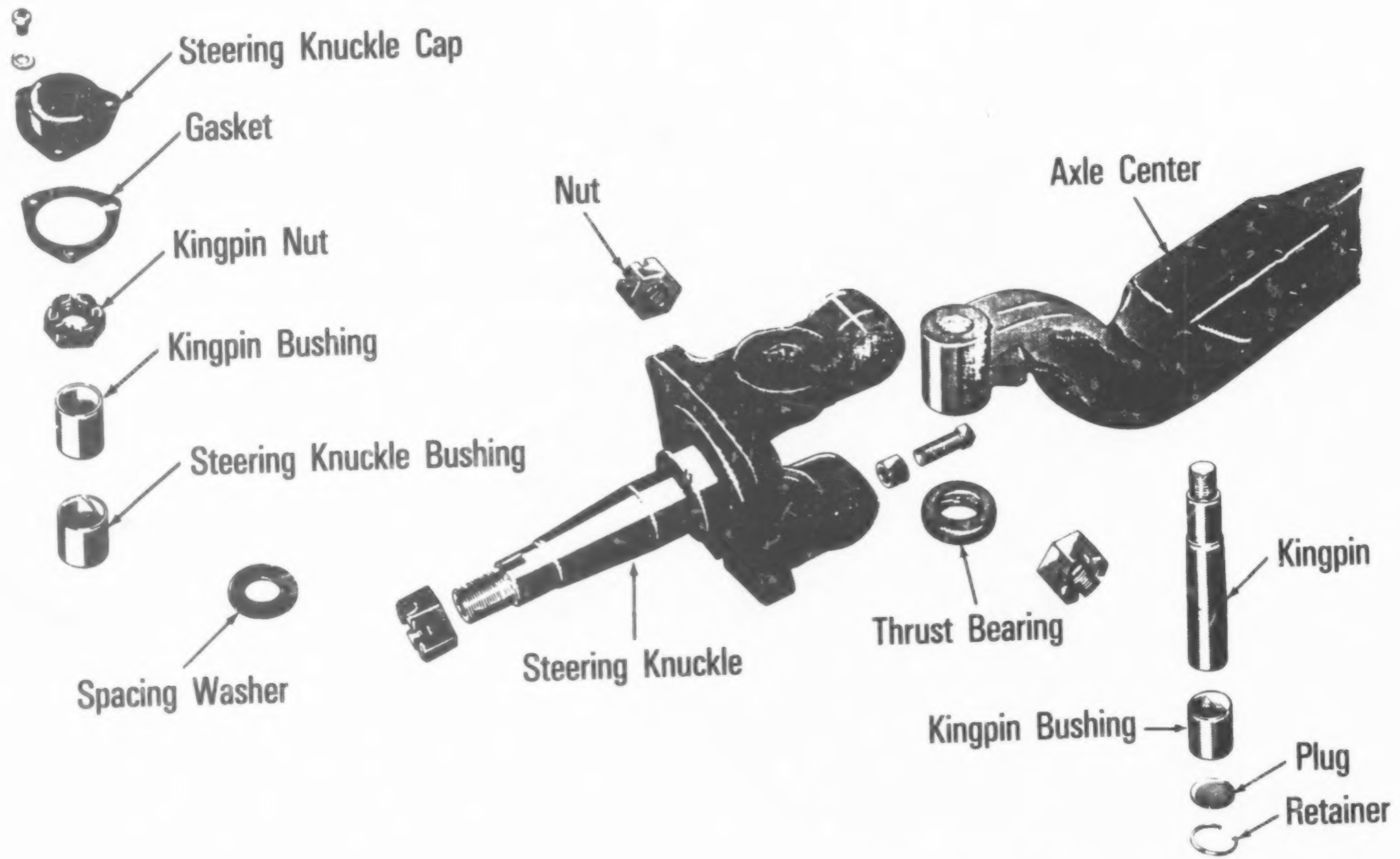

Steering Wheel
Tie Rod
Steering Shaft
Power Steering Cylinder
Steering Arm
Hydraulic Fluid Reservoir
Gear Box
Pitman Arm
Drag Link
Steering Knuckle
Spindle

Visual 11.2

Steering Gear and Pitman Arm

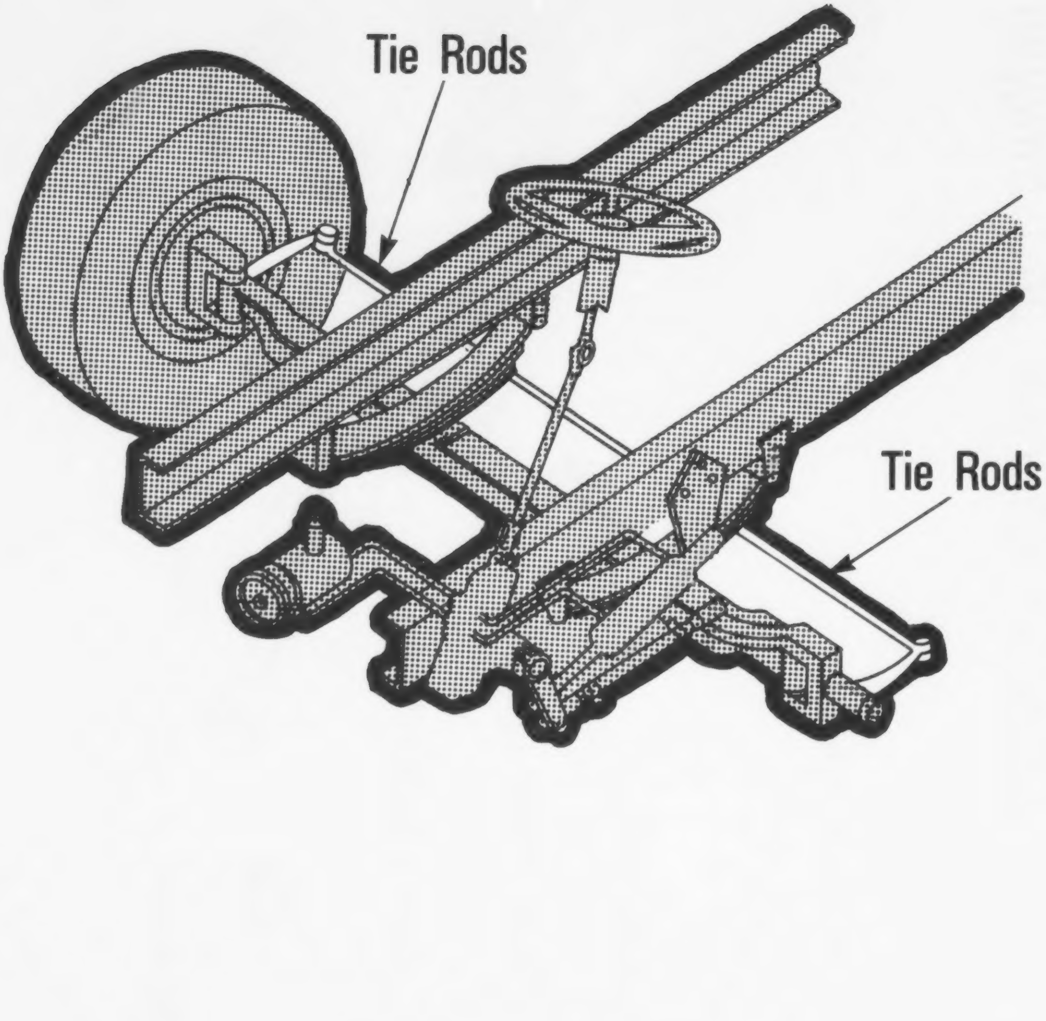

Steering Wheel
Steering Shaft
Pitman Arm
Gear Box
Pitman Arm

Steering Knuckle and Kingpin

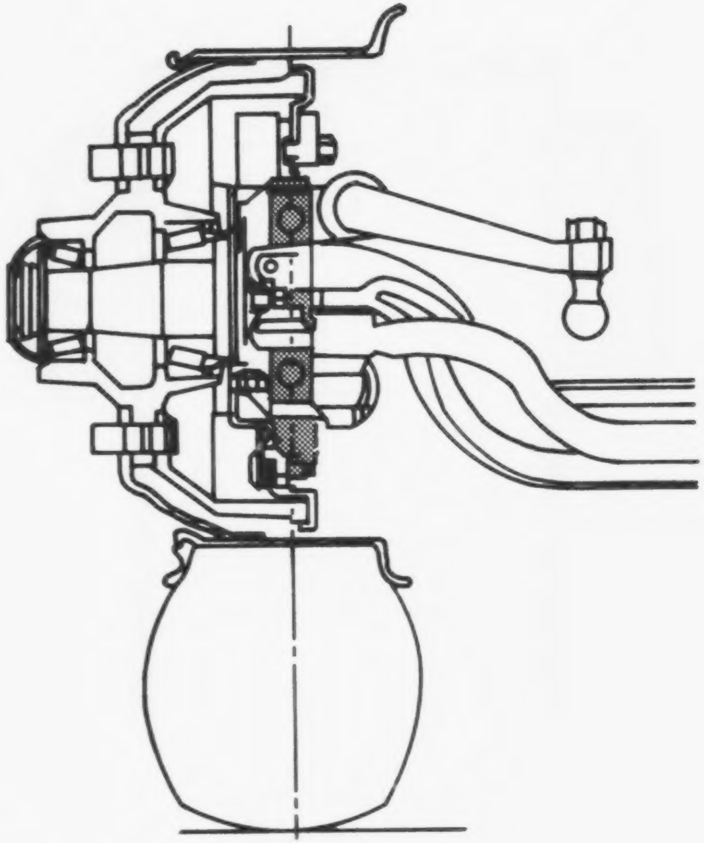

Steering Knuckle Cap
Gasket
Kingpin Nut
Kingpin Bushing
Steering Knuckle Bushing
Spacing Washer
Nut
Steering Knuckle
Axle Center
Thrust Bearing
Kingpin
Kingpin Bushing
Plug
Retainer

Visual 11.4

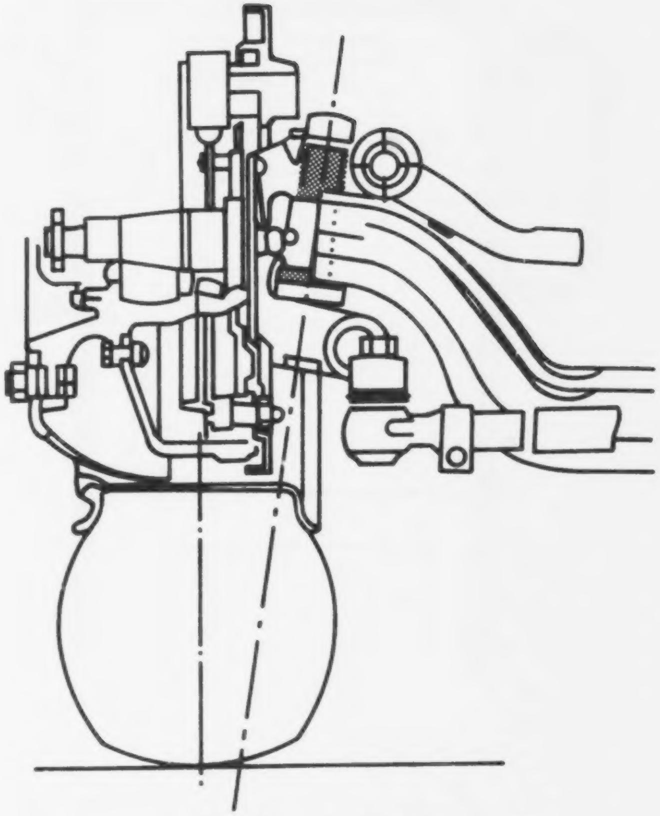
Tie Rods


Tie Rods
Tie Rods

Center Point and Inclined Kingpins



Center Point Design

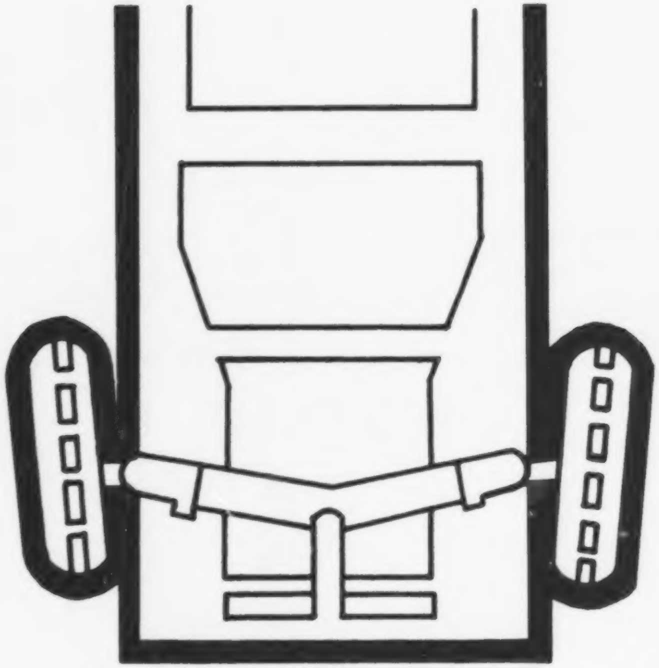


Inclined Design

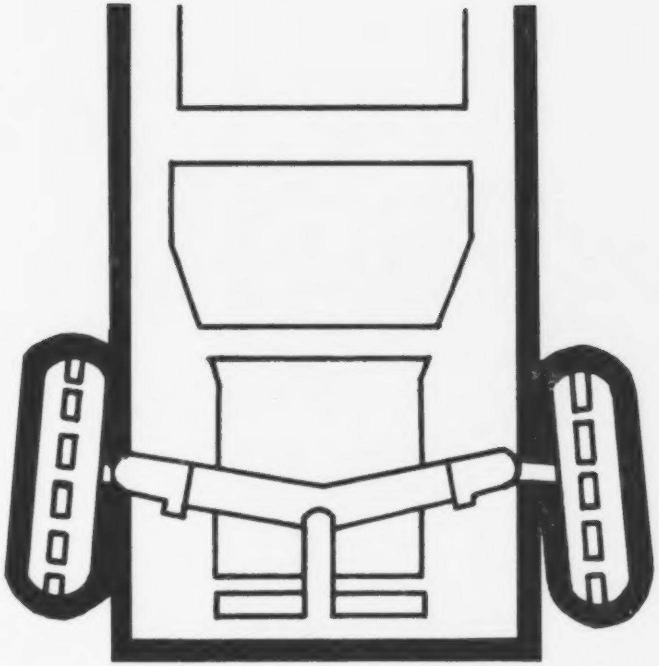
READEX FICHE

Visual 11.6

Front Axle Toe-In, Toe-Out



Toe-In

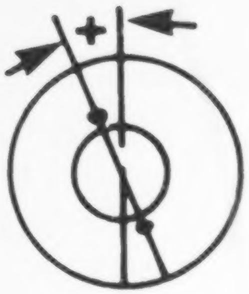


Toe-Out

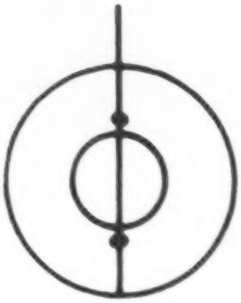
Visual 11.7

Caster and Camber

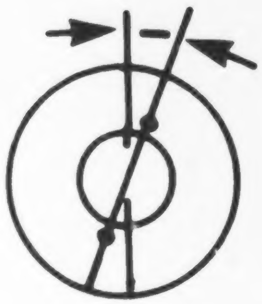
Caster



Positive
Caster

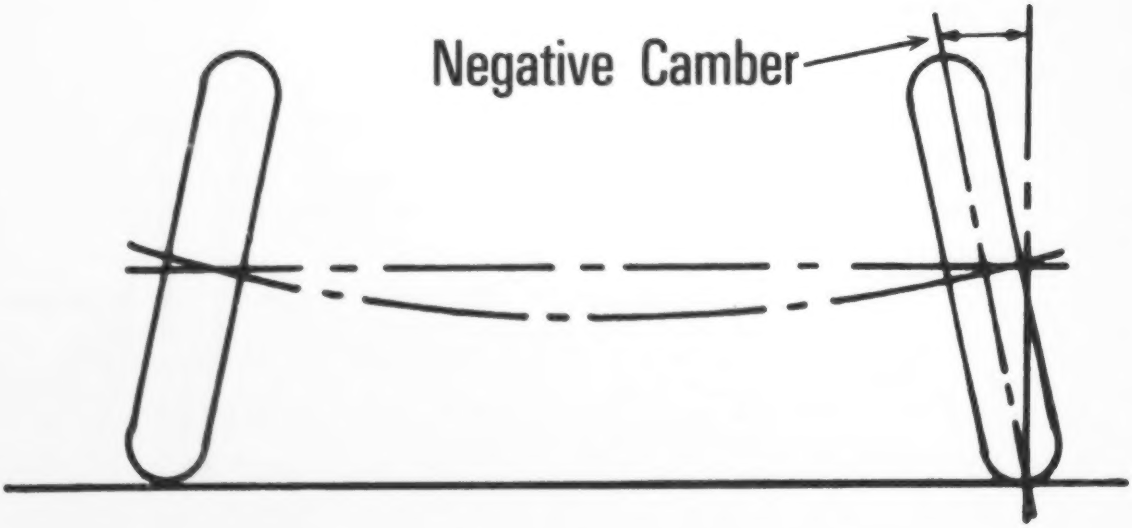


0-Degree Caster



Negative
Caster

Camber


Negative Camber

12. COUPLING SYSTEMS (30 minutes)

Introduction

The purpose of this topic is to give the students a fundamental knowledge of coupling systems for

- Tractor and semi-trailer
- Tractor, semi-trailer and full trailer
- "B" train doubles
- Dromedary tractor and semi-trailer

Purpose

Coupling systems provide the mechanical means to connect the vehicles into a combination vehicle.

Basic Components

Fifth Wheel (Fixed and Sliders)

- Fifth wheel
- Upper fifth wheel
  - King pin
- Slack adjustor
- Landing gear
- Converter dolly
  - Draw bar
  - Draw bar eye
  - Pintle hook
  - Safety chains or cables
- Air and electrical lines, while part of the Coupling System, are covered as part of the lesson on Braking Systems.

Basic Components

Fifth Wheel

- The fifth wheel, located at the rear of the tractor, connects the tractor to the trailer
- The fifth wheel is the tractor connecting mechanism for tractor and semi-trailer combinations as well as tractor and full trailers

Function

- The fifth wheel allows the tractor-trailer combination to maneuver easily while providing necessary stability to the trailer
- The operating principle of the fifth wheel dates back to the horse and wagon days
- On a wagon the tongue is coupled to the front axle which allows articulating front axle movement

The wagon articulating front axle and the tractor fifth wheel serve the same purpose--they permit the driver to steer with reduced risk of overturning.

The fifth wheel, however, serves other purposes beyond that served by the wagon tongue, the most important of which is to support and carry the front end of the semi-trailer.

Visual 12.1 Fifth Wheel Parts

Fifth Wheel Parts

The fifth wheel consists of several functional parts. The parts most related to securing the trailer and operation of the unit are

- Skid plate
- Skid ramp
- Throat
- Coupler jaws
- Locking mechanism
- Skid ramp stop

Skid Plate

The skid plate is the surface area of the fifth wheel. The upper fifth wheel on the semi-trailer rests on the fifth wheel skid plate.

Problems

Most problems associated with the skid plate are caused by the skid plate being dry; in need of lubrication

A dry skid plate increases wear to the plate, the upper fifth wheel face (plate) and the king pin

When a fifth wheel plate is dry, moisture is likely to form (and freeze), thus interfering with turning the vehicle

Moisture condensation and freezing are most likely to occur on long hauls when the semi-trailer remains coupled for several days

Skid Plate Maintenance

The requirements for maintaining the skid plate aren't excessive

The most important maintenance factor is to lubricate at regular preventive maintenance schedules

Proper lubrication has several advantages

The principle advantage is it reduces wear to upper and lower fifth wheel and kingpin

Importantly also lubrication applied to the plate helps lubricate the fifth wheel: throat, locking mechanism, and jaws

Thus proper lubrication of the skid plate "guarantees" proper maintenance of other parts

Overlubrication

- Overlubricating can cause some problems; however, overlubrication is not as serious as operating with a dry skid plate
- The best solution is to properly lubricate the plate
- Problems of overlubricating stem from the idea "a little grease is good so a lot of grease must be better"
- The major problems caused by overlubricating are
    - Grease picks up dirt and creates a "grinding compound" that leads to excessive wear
    - Grease is pushed off creating a mess on the vehicle and ground
    - Excessive grease can get in the jaws causing closing problems

Skid Ramp

The skid ramp at the back of the fifth wheel, helps by sliding under the trailer lifting it up so it settles down flatly on the tractor as it depresses

Throat

The throat is a slotted-V shaped area of the fifth wheel which helps direct the kingpin to the coupler jaws

Coupler Jaws

The coupler jaws lock around the kingpin to hold the trailer to the tractor

Maintenance

- Wear to the coupler jaws is common
    - The jaws should be checked at regular maintenance intervals for wear
    - Proper checking for wear requires that the jaws be checked with a gauge designed to measure wear. Since a small amount of wear will result in coupling slack, eyeballing wear is insufficient
    - Maintenance of jaws entails proper lubrication
        - If grease is a permissible lubricant, grease applied to the skid plate should be sufficient
        - Excessive grease should be wiped clean
        - A light coat will prevent wear
        - If manufacturer suggests lubricants other than grease (i.e., diesel fuel), the manufacturer's recommendations should be followed

Jaw Locking Mechanism

Holds the fifth wheel jaws in place around the kingpin to secure the connection of tractor and trailer

Types

- There are two standard types of locking mechanisms
  - Mechanical - hand set
    - Has spring loaded jaws
    - Must be adjusted to compensate for normal jaw wear and assure a snug fit on a new kingpin
  - Compression - air activated
    - Contains a built-in rubber block that compresses behind jaw to keep kingpin in place
    - The compression mechanism is self-adjusting to the kingpin

Skid Ramp Stop

Located at back of the mounting mechanism of the fifth wheel

Purpose

- Its purpose is to keep the kingpin from being pushed too far into the coupler jaws, thus reducing damage to the fifth wheel
- While it helps prevent damage, caution must still be exercised not to back too quickly into the trailer while coupling

Types of Fifth Wheels

There are two types of fifth wheels, fixed and sliding. They both satisfy the same purpose

Visual 12.2 Fixed Fifth Wheel

Fixed Fifth Wheel

The fixed fifth wheel has a permanent mount which holds the wheel in one location

- The fixed fifth wheel costs less than a sliding fifth wheel
- The fixed fifth wheel is appropriate when the same trailer is frequently used and the same load requirement commonly prevails

Visual 12.3 Sliding Fifth Wheel

Sliding Fifth Wheel

The sliding fifth wheel has a permanent mount with sliders which permit moving the fifth wheel forward or backward to change the location where the coupling of the tractor and semi-trailer occurs

Advantages

- The sliding fifth wheel offers greater flexibility than the fixed fifth wheel in meeting changing needs. It more readily accommodates
  - Changing load requirements
  - Changing vehicle length needs in response to legal requirements
  - Different trailer types

Benefits to Maneuvering

- The sliding fifth wheel can be set for the load and load distribution to achieve optimum steering and traction
  - The fifth wheel can also be set too far forward or backward which will lessen steering control and traction

    Forward--If the fifth wheel is too far forward: (1) the weight distribution is too little on the rear wheels and traction is reduced, and (2) too much on the front wheels causing oversteering (e.g., responding too quickly)

    Backward--If the fifth wheel is too far back, the front end is "lifted" resulting in understeering (e.g., not responding enough or soon enough to steering)

Slide Mechanism

A track-like guider on which the position of the fifth wheel is changed

Slide Control Device

There are two types of controls used to adjust the setting of the sliding fifth wheel

Manual Control--Hand activated and the wheel is moved manually

Remote Control--The remote control permits movement by using a control device which is usually located in the cab

Remote Control Operation

- The device is usually air-activated
  - The fifth wheel is automatically moved by activating the control releasing pins and moving the tractor forward or backward
  - Trailer brakes must be set when adjusting the slider position for the fifth wheel

Slide Locking Mechanism

A locking device to hold the fifth wheel in its desired position for use

Types of Slide Locking Mechanisms

- There are two designs of slide locking mechanisms
  - Pin - pins are used that are inserted into matching holes in the slider track
  - Plunger - plungers are fitted into a row of slotted holes in the center base of the the fifth wheel

Visual 12.4 Elevating Fifth Wheel

Elevating Fifth Wheels

The height is adjustable on some fifth wheels. They are called liftable fifth wheels

Purpose

The lift fifth wheel serves two purposes: (1) to change the height of the fifth wheel when coupling and uncoupling, and (2) to change the height of the trailer for loading and unloading cargo

Benefits

- The lift wheel is advantageous when
  - Trailers are frequently changed (e.g., moving them around the dock)
  - When loading/unloading are frequently required

Wear

- The lift fifth wheel if used properly can reduce wear to the skid plate by adjusting the lift to better accommodate the position of the trailer and kingpin when coupling. Proper use results in less damage as the fifth wheel skid plate contacts the upper fifth wheel where the kingpin is located

Operation

- The lift wheel works on the same principle as a dump truck lift
  - Lifts are designed to be hydraulically- or air-activated

Proper Fifth Wheel Mounting

Fixed, sliding, and lift type fifth wheels must be properly mounted on the tractor

Factors to Consider in Mounting

- Follow the manufacturer's instructions and specifications for parts
- Make sure proper space is provided for free operation of tires and the trailer landing gear
- Make sure trailer swing clearance is provided--e.g., when tractor is turned completely left or right
- Make sure the mounting provides clearance needed for single or tandem axles
- Make sure the height at which the fifth wheel is placed results in a level unit
  - A low fifth wheel will carry the trailer nose down
  - Causes tractor springs to deflect excessively which may result in the trailer contacting the tractor tires

Improper Mounting

- The primary ways in which fifth wheels are improperly mounted include:
  - Using U-bolts to fasten the brackets
  - Using mounting parts designed for other fifth wheels
- Problems caused from improper mounting beyond those mentioned previously include wear to the fifth wheel skid plate, king pin, and in some instances to the tractor

Placement of Fifth Wheel

The fifth wheel is permanently attached to the trailer. The fifth wheel may be placed on the tractor (longitudinal placement) to meet load requirements (e.g., common weight and distribution)

Factors to Consider in Placement

The same factors applicable to setting a sliding fifth wheel apply to the placement of the fifth wheel

The placement must account for vehicle handling--especially the effect of placement on tractor steering and traction

Visual 12.5 Upper Fifth Wheel on Trailer

Upper Fifth Wheel on Trailer

The upper fifth wheel is the plate attached to the trailer

Purpose

Its purpose is to hold and anchor the kingpin

Operation

The upper fifth wheel (plate) rests on the skid plate of the tractor fifth wheel

Construction

The plate is usually made of heavy steel

Maintenance

Maintenance of the plate is unnecessary

It is lubricated by the grease from the skid plate

Problems

While maintenance of the plate is essentially nonexistent, the plate should be checked for

Cracks--cracks have been known to occur in thick steel plates

Looseness--bolts or anchors have been known to work loose causing the plate and kingpin to shift

Visual 12.6 Kingpin and Kingpin Location on Trailer

Kingpin

The kingpin held by the upper fifth wheel plate is the object to which the fifth wheel connects to couple the tractor and semi-trailer

Requirement

- Kingpins are usually constructed from heavy steel
  - They must be constructed from a heavy, sturdy metal
  - The pin has to be 2-3 inches in diameter
  - It must be long enough to fit all the way down into the coupler jaws
    - The actual length needed depends on the height and placement of the fifth wheels

Checking the Kingpin

- The kingpin should be checked for appropriate length and wear

Length

- Each trailer needs to be checked since the pin is located on the trailer and may vary from trailer to trailer

Wear

- Wear is most likely to occur when the fifth wheel jaw metal is stronger than the metal used to construct the kingpin
- Kingpins should be replaced when 1/8" slack exists between the pin and coupler jaws

Slack Adjuster

A device used with fifth wheels to reduce the slack between the fifth wheel jaws (yoke area) and the kingpin

The slack adjuster adjusts the locking mechanism of the fifth wheel so it will fit snugly and securely around the kingpin

Function

- The purpose is to reduce normal slack at the point of coupling
  - The adjuster should not be used to compensate for worn parts

Need

- Adjusters are most commonly available and used with mechanical locking mechanisms
- Compression locking mechanisms have less of a slack problem and adjusters are used.

Operation

- The adjustment for mechanical locking mechanisms is made by setting the adjusting nut
  - The adjusting nut reduces the size of the yoke of the adjuster, thus reducing slack
  - The adjusting nut has a lock, "lock adjust nut", which must be loosened for making an adjustment, and tightened back, locked, to keep the adjustment of the yoke where it is set

Benefit

- The proper use of slack adjusters reduces wear and makes drivers a bit more comfortable
  - Wear--proper adjustment lessens wear to the kingpin
  - Driver comfort--the driver experiences a few less jerks from the trailer when accelerating and slowing which are caused by a coupling that is not snug

Visual 12.7 Landing Gear

Trailer Support commonly called Landing Gear

A support located beneath and towards the front of the trailer.

Function

- The purpose of the landing gear is to hold the nose, or front, of the trailer up, to support the semi-trailer, when detached from the tractor

Operation

- When the trailer is coupled, the landing gear is lifted and remains beneath the trailer
  - The landing gear must be lowered when coupling and when the trailer is not in use
  - The trailer should not be rolled with the landing gear down even when wheels or casters are provided (increases damage potential and wear to the gears)
  - The landing gear shouldn't be used under conditions where there is side, front or rear force. The gears aren't designed to withstand these forces
- Lowering and raising the landing gear is achieved by a mechanical or hydraulic lift device
  - Mechanical--The desired position of the landing gear is achieved by turning a crank alongside the trailer
  - Hydraulic--The desired position is achieved by the flow of oil under pressure
- The hydraulic
  - Requires greater maintenance than the mechanical
  - Costs more than mechanical at purchase
  - Can be used to easily vary the height of the trailer while loading and unloading

Replacement

- Landing gears are designed to last the life of the trailer under normal operation
- Most replacement is necessitated by abuse, misuse, or poor maintenance

Reasons for Repair

- Problems which typically lead to damage and repair
- Moving trailer when it is supported only by the landing gear
  - Dropping too far (lowering)
  - Impact by dropping
  - Overloading
  - Rolling legs up too far and stripping the screw threads
  - Impact to the sides of legs

Signs for Repair

Mechanical

- Difficulty shifting from high to low position and back
- Difficulty in cranking

Hydraulic
  Listing to one side (oil seal leak)

Mechanical and Hydraulic
  Cracks in structure

Visual 12.8 Converter Gear Assembly

Converter Gear Assembly commonly called a Dolly

A set of wheels, single or tandem axle, which connects to the front of a semi-trailer

Function
- Converter gear or dolly is used only with semi-trailer. The dolly enables connection of an additional semi-trailer to the vehicle unit
- The dolly becomes the front axle of the second trailer

Operation
- The dolly serves as the fifth wheel for the second semi-trailer
- The dolly
  - Improves steering over a non-articulating axle
  - Permits heavier loads to be pulled than can be achieved by any one larger semi-trailer
  - Typically used in coupling two short semis (e.g., 27 feet) although, where legally permissible, the dolly is used with larger trailers

Connection/Setup
- Dolly connects to second semi-trailer
- A pintle is used for coupling to rear of lead trailer
- Proper coupling with dolly always includes using safety chains

Use of Dolly
- Several factors should be considered when using a converter dolly Factors are
  - Less stable than a single, thus placing more demands on the driver for safe operation
  - Overall vehicle length restrictions (laws) must be met
  - Per-axle restrictions on the load must be met for legal and safe operation

Visual 12.9 Drawbars

Drawbars

The tongue or front part of the converter dolly which is connected to the lead trailer.

- A long bar, of heavy construction
- On its end (end toward front trailer), it has a circular opening called a dolly eye
- The eye is used in connecting to the lead trailer and it becomes part of the "hitching" or coupling mechanism.

Purpose

- Sometimes called a tow bar
- Connects to front (lead) trailer to permit towing

Attachment

- Needs to be aligned so it is level to eliminate pole vaulting (pitching forward of the trailer) when decelerating
- Looseness contributes to trailer wear

Connection

- Connected to front trailer by pintle hook

Visual 12.10 Types of Pintle Hooks

Pintle Hooks

The pintle hook, located at the back of the lead trailer, is the device which couples the two semi-trailers

Function

- The pintle hook inserts into the dolly eye of the draw bar to connect the two trailers
- It operates similarly to conventional trailer hitches used on passenger vehicles towing trailers

Types

- All pintle hooks serve the same purpose; however, there are two basic types
  - Rigid--Stays in same position on the lead trailer
  - Swivel--Stays in same location on the trailer, but permits a small lateral flex to accept the dolly eye

Locking Mechanism

- The pintle hook (a complete circle when closed) closes and locks into the dolly eye
- There are two basic types of locking mechanisms to prevent the pintle from opening and coming loose during operation
  - Spring load--Where spring tension keeps the pintle locked
  - Air operated--Where air pressure holds the pintle in its locked position

Tractor Connectors

A number of converter gears are designed in a way that allows it to be connected to the rear of the tractor.

Advantages

- Reduced coupling time
  - Converter doesn't have to be uncoupled from trailer
- Increased load
  - Converter becomes a second set of duals
  - Makes a single axle tractor function as a tandem axle tractor
- Unnecessary to wait for another tractor

Design

Different manufacturers use different systems for correction
All permit quick connection of converter gear to tractor
In one model, the converter fifth wheel can be folded out of the way to allow a trailer to be connected to tractor fifth wheel.

Safety Chains

A pair of heavy chains on the dolly to be connected to the trailer

Function

Used with converter dolly
Provides added safety in use with drawbar and pintle hook
Should always be connected when vehicle is used
Should never be used without properly connected drawbar (i.e., to pull trailer)

B-Trains

Combination of two trailers in which the points of articulation are reduced in comparison with normal doubles
Discussed in Unit 1.7, Coupling and Uncoupling
Improved handling and stability by reducing points of articulation

Visual 12.11 B-Train

B-Train

Trailer rear axle placement and coupling area
The pintle hook and drawbar is eliminated in B trains
Tandem rear axles are placed where the second axle of the tandems behind the first trailer
The fifth wheel is mounted above the second axle eliminating the converter gear
The second trailer couples to the first, using the fifth wheel as in normal fifth wheel coupling.
Basic coupling system and components are the same as discussed under Basic Coupling

Visual 12.12 Dromedary Tractor

Dromedary Tractor

Has a cargo box between the cab and the fifth wheel
In effect the fifth wheel is moved back
The cargo box is also called a Drom box

Purpose

It provides additional cargo space, giving carrying advantage similar to using a small trailer and semi-trailer combination

Connecting

Connect like any standard tractor and semi-trailer
Coupling of the fifth wheel merely occurs farther back from the cab, at the end of the Drom box

Operation

- Unit has only one point of articulation
- Handling is improved by tandem front steering axles and added weight over the axles

Locating and Recognizing Problems

During inspection, the driver must inspect

Fifth Wheel

- Adequate lubricating of fifth wheel
  - Sufficient to lubricate and prevent moisture
  - Not so much as to collect dirt, or prevent jaws from closing
- Jaws
  - Excessive slack when coupled with Kingpin
  - Check wear with gauge
- Skid plate
  - Wear
  - Cracks
- Bolts
  - Looseness of bolts
  - Shifting plate position

Kingpin

- Wear is primary problem
  - Kingpin must be replaced periodically
  - If more than 1/8" gap between kingpin and jaws
- Bolts
  - Check for looseness, shifting of pin position

Landing Gear

- Usually inspect for cracks in structure
- Mechanical
  - Crank gear and check for resistance
- Hydraulic
  - Check for
    - Imbalance (listing to one side)
    - Oil leakage

Operation

- Watch for symptoms of coupling problems
- Poor vehicle steering response may be due to:
  - Improperly positioned sliding fifth wheel
    - Mounted too far back
    - Takes weight off front wheel
  - Inadequately lubricted fifth wheel
    - Binding occurs during turn
    - Resists turn

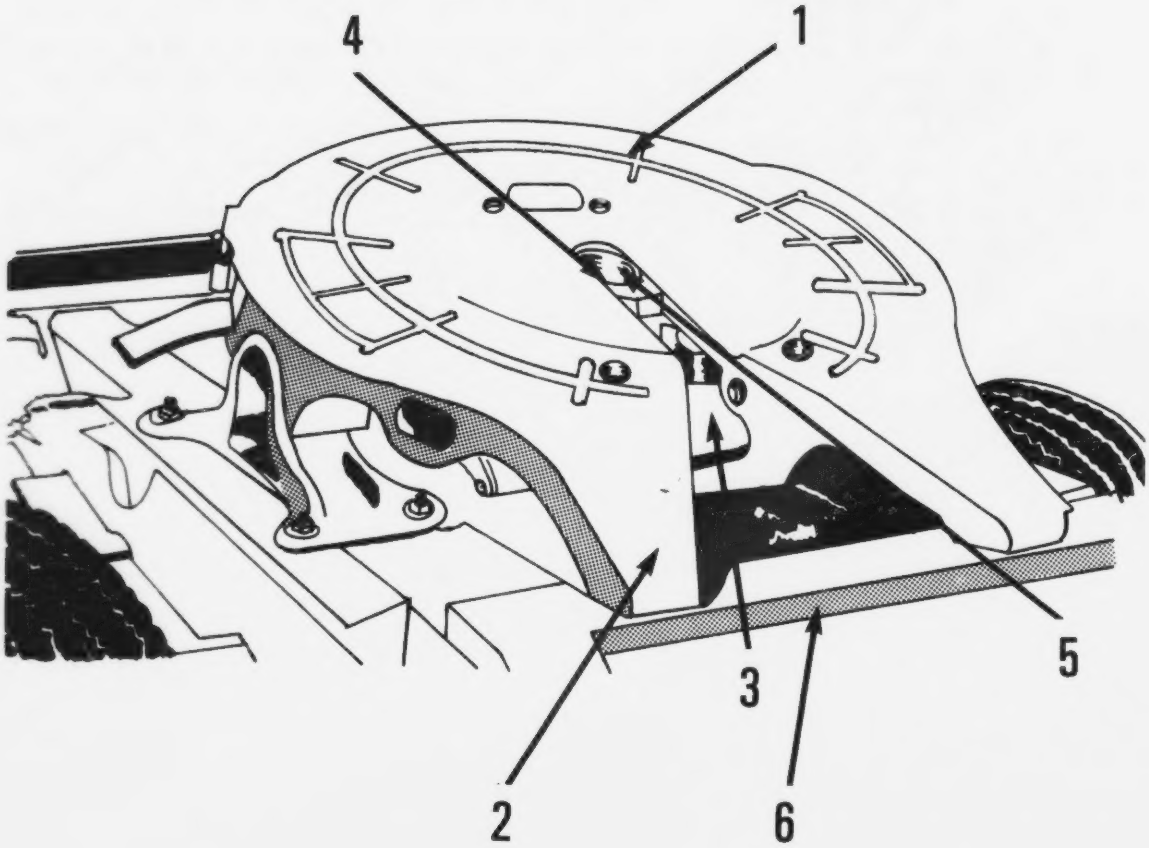
Recap

Coupling

- Drivers need to know various means of coupling tractor-trailer and trailer combinations
- Drivers should be familiar with the coupling mechanisms so they can
  - Couple the unit
  - Perform proper inspection of the coupling
  - Identify maintenance requirements
  - Anticipate and respond to the effect of coupled units on vehicle handling
- Drivers also need to know how they can couple, especially with sliding fifth wheels to achieve the optimum steering response and maintain traction to the drive wheels
  - The fifth wheel, however, serves other purposes beyond that served by the wagon tongue, the most important of which is to support and carry the front end of the semi-trailer.

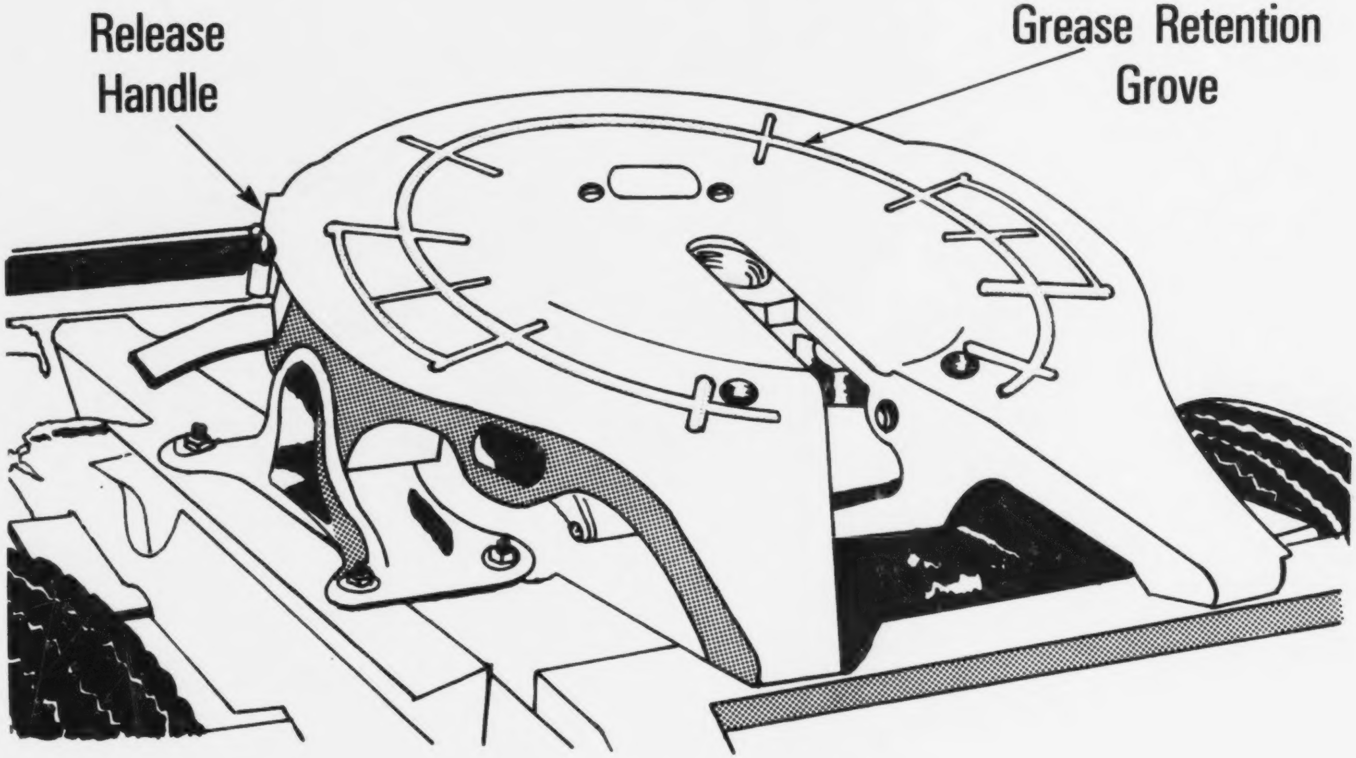
Visual 12.1

Fifth Wheel Parts



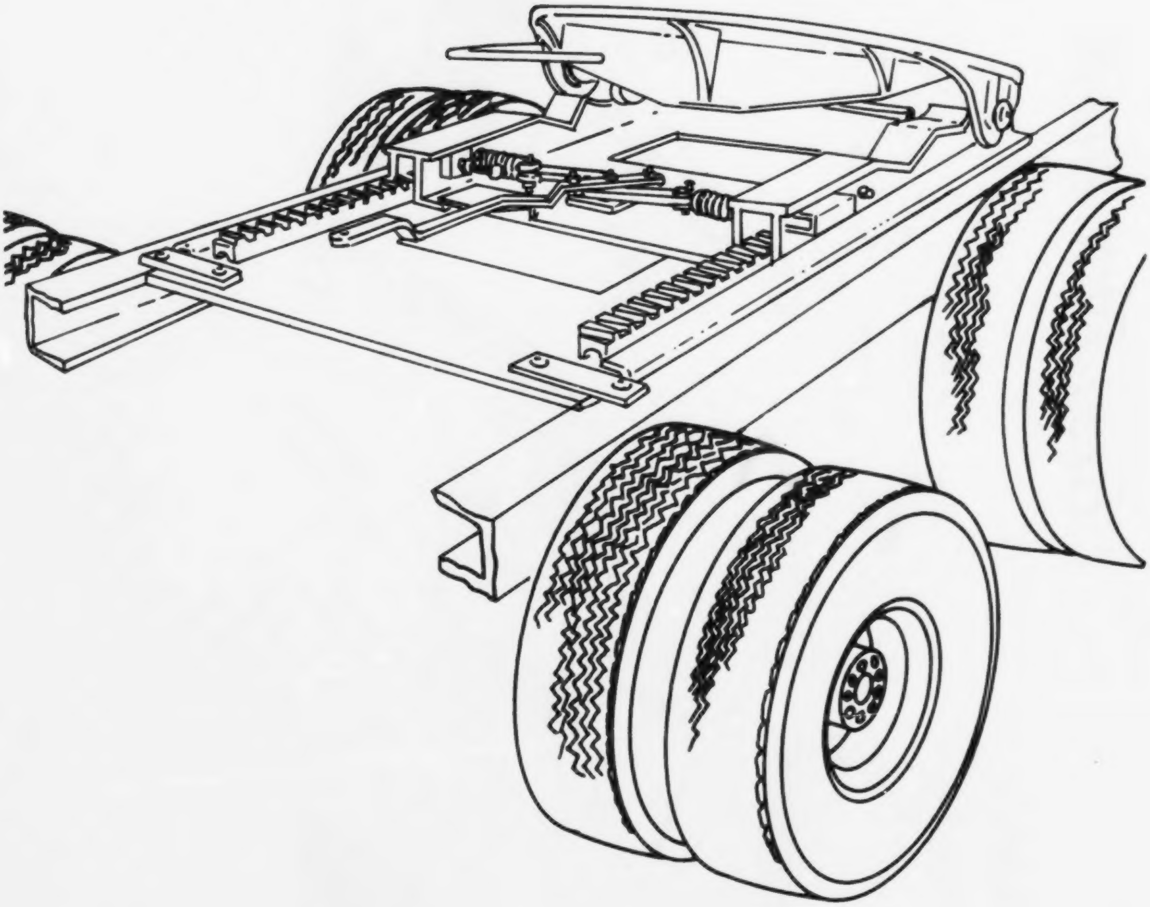
1. Skid Plate
2. Skid Ramp
3. Throat
4. Coupler Jaws
5. Locking Mechanism
6. Skid Ramp Stop

Fixed Fifth Wheel


Release
Handle
Grease Retention
Grove

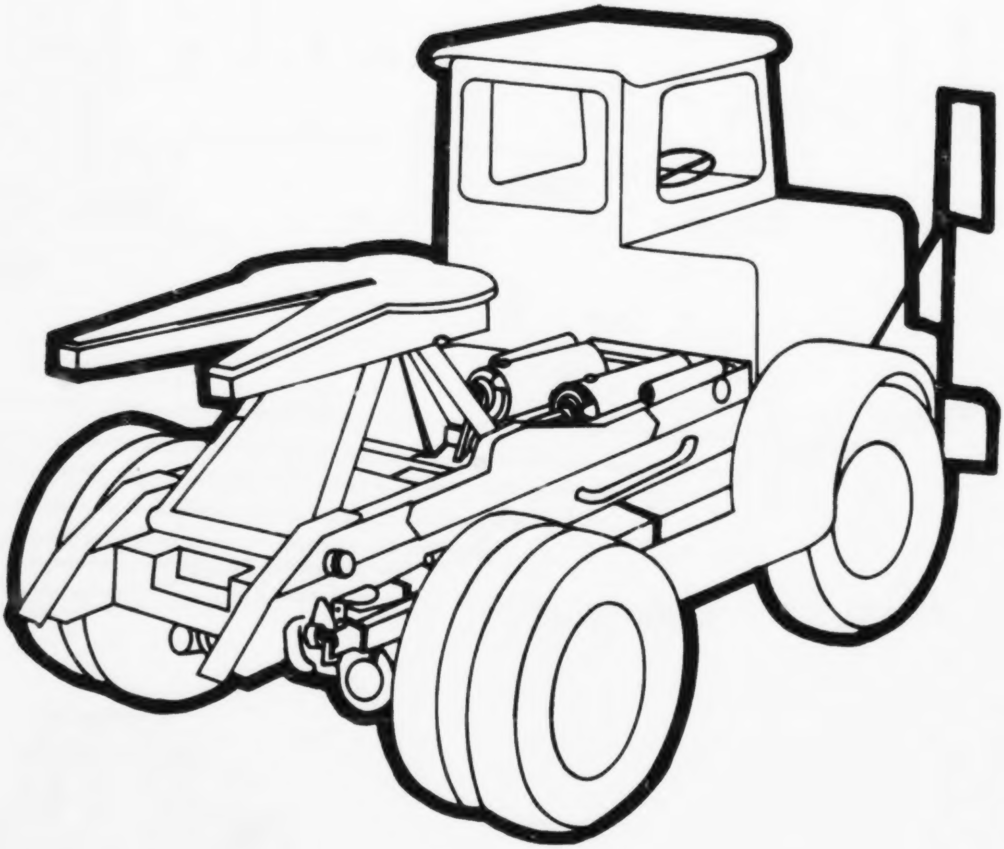
Visual 12.3

Sliding Fifth Wheel



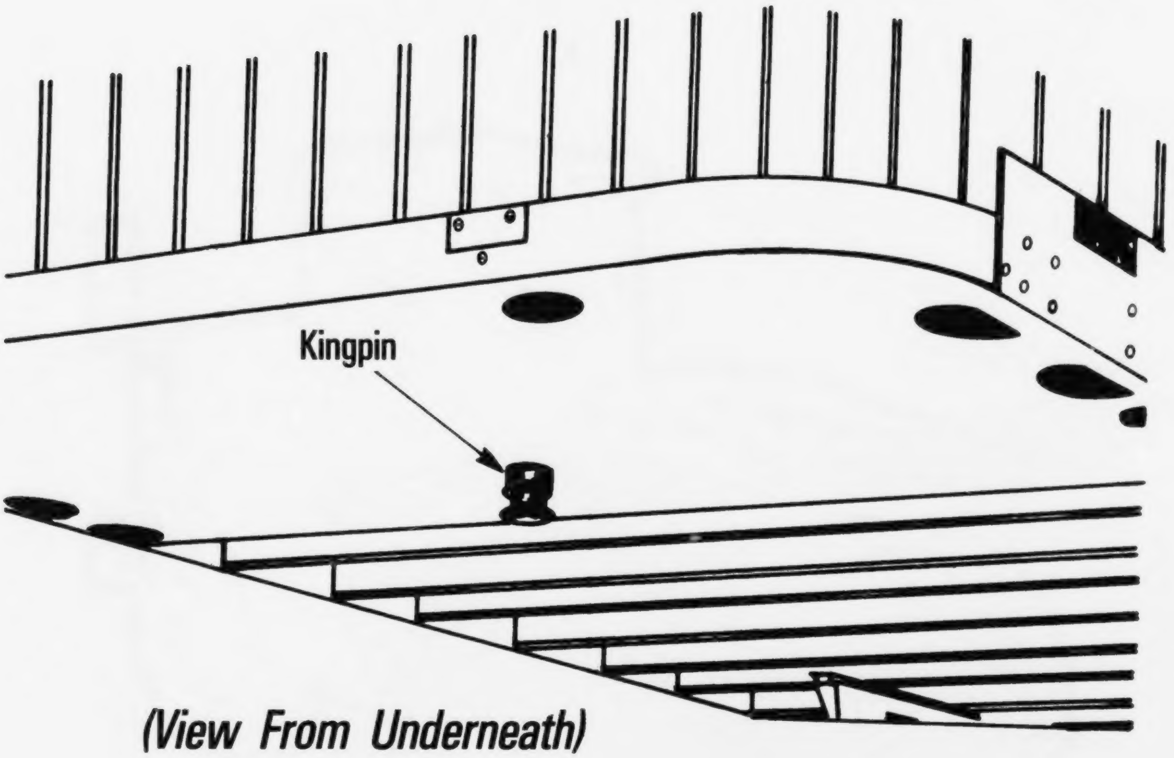
Visual 12.4

Elevating Fifth Wheel

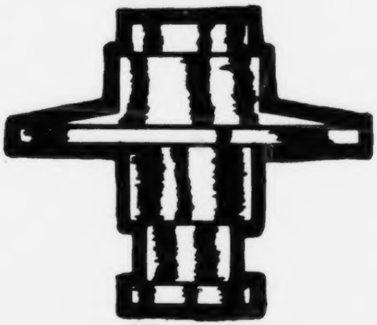


Visual 12.5

Upper Fifth Wheel Plate



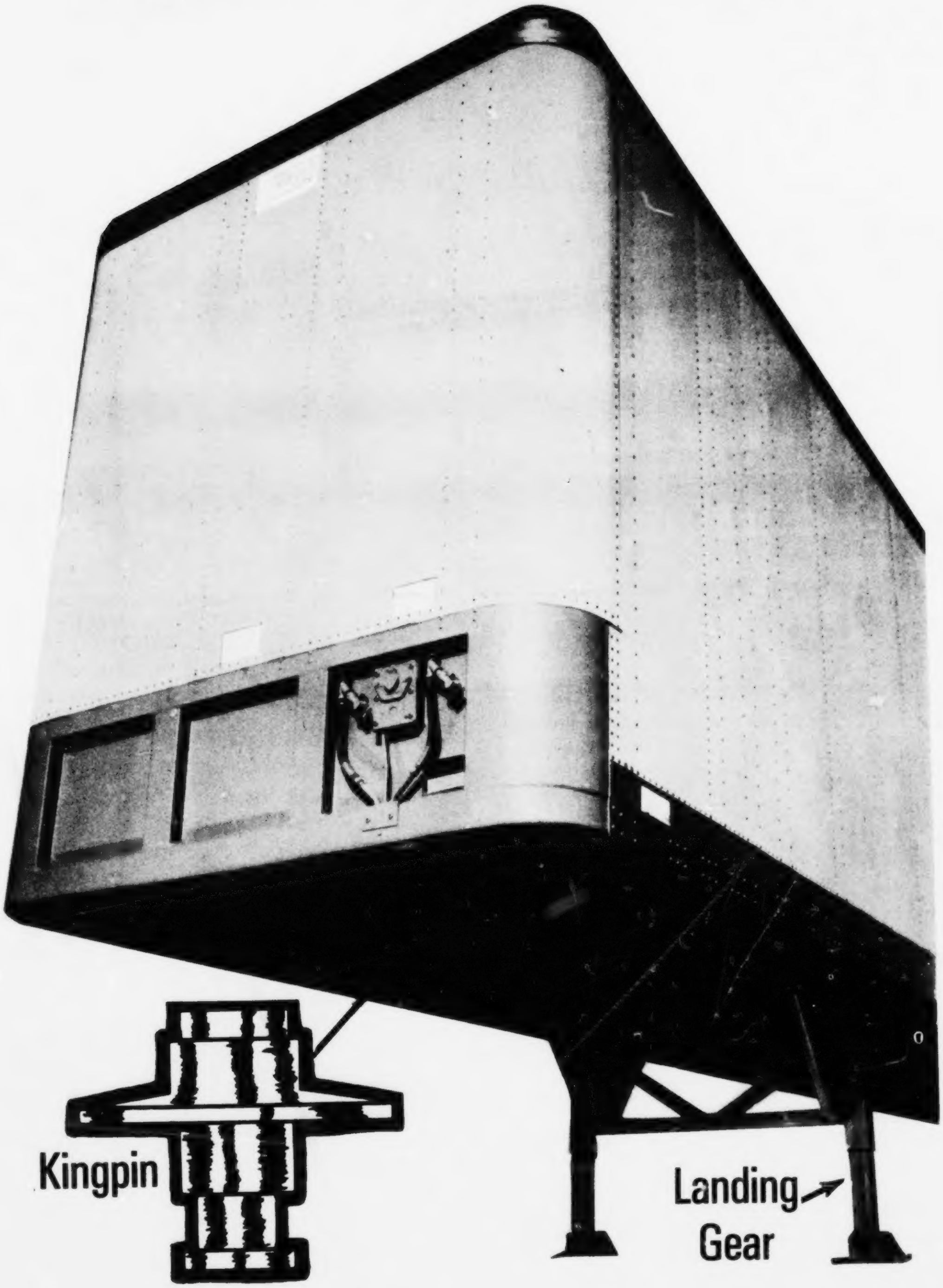
(View From Underneath)



Kingpin

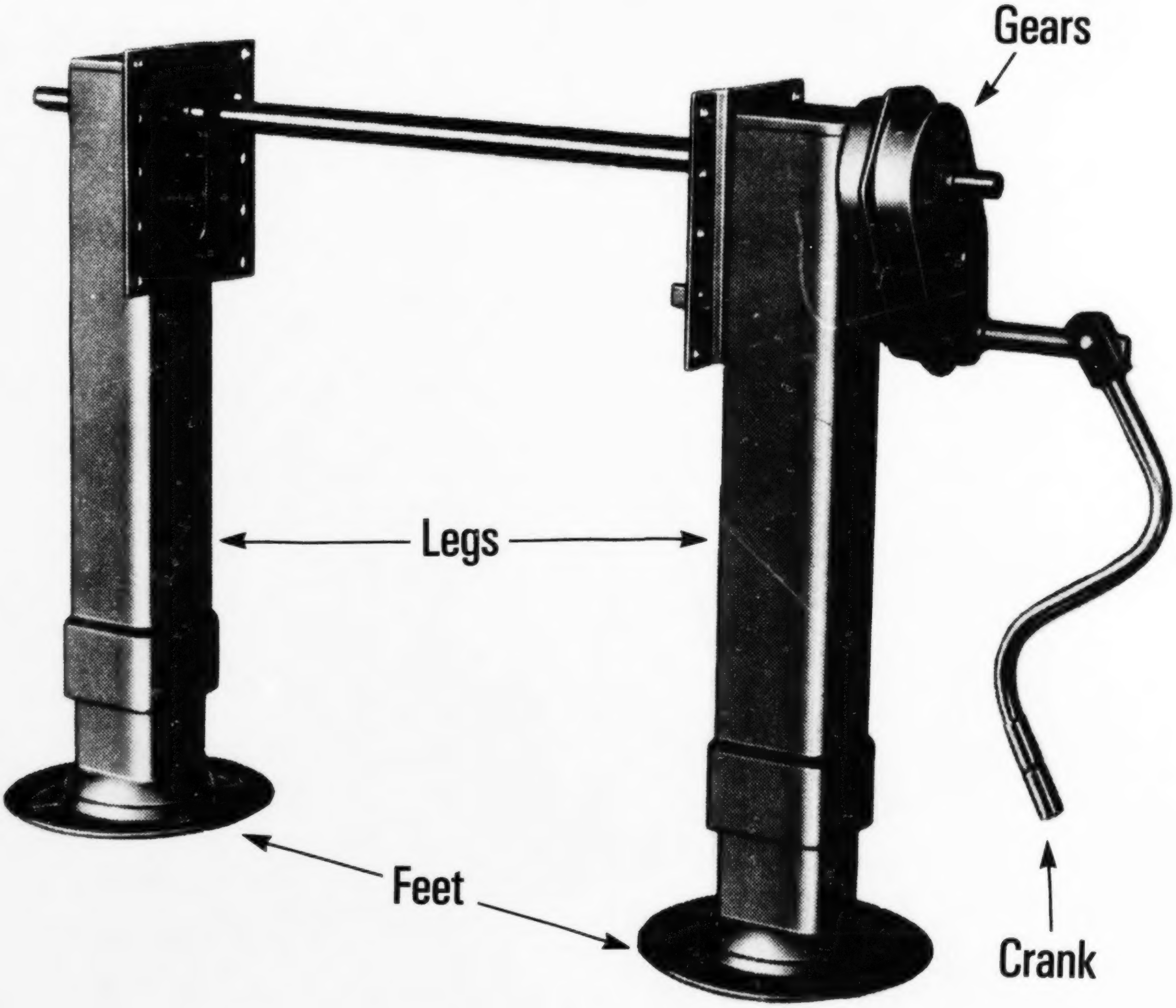
Visual 12.6

Kingpin and Kingpin Location


Kingpin
Landing Gear

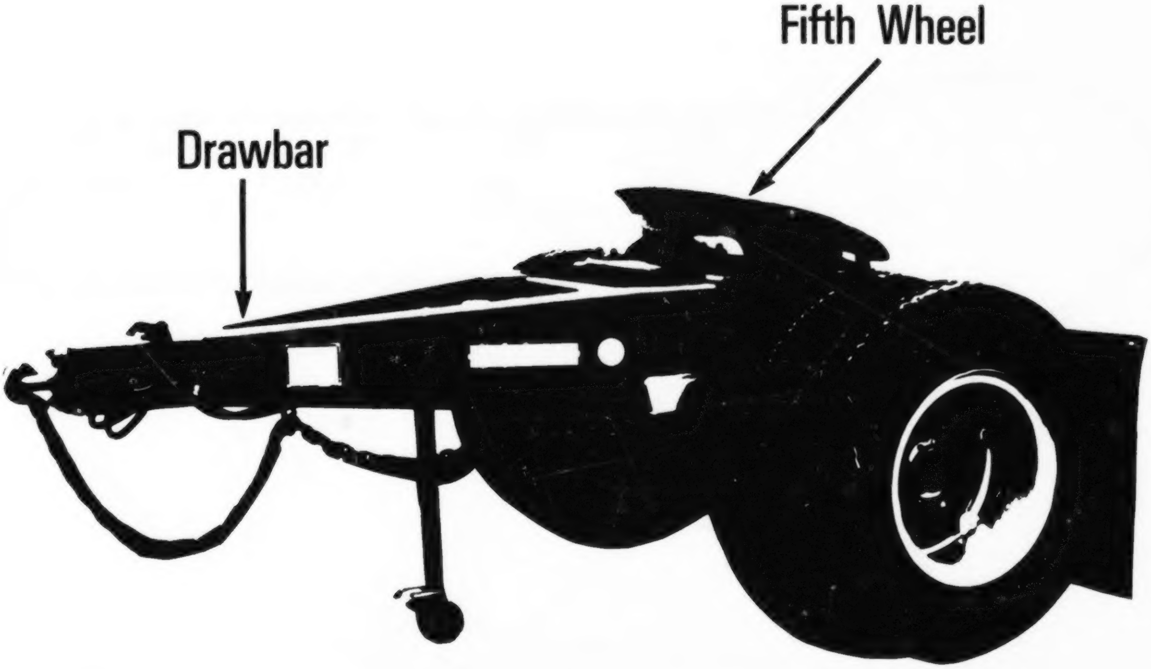
Visual 12.7

Landing Gear


Gears
Legs
Feet
Crank

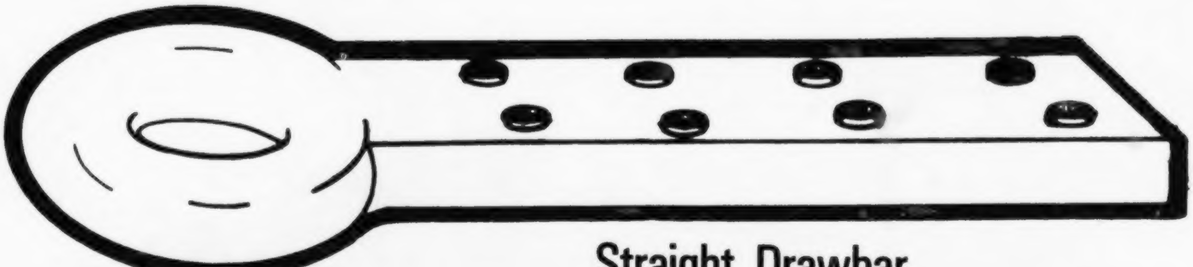
Visual 12.8

Converter Gear


Fifth Wheel
Drawbar

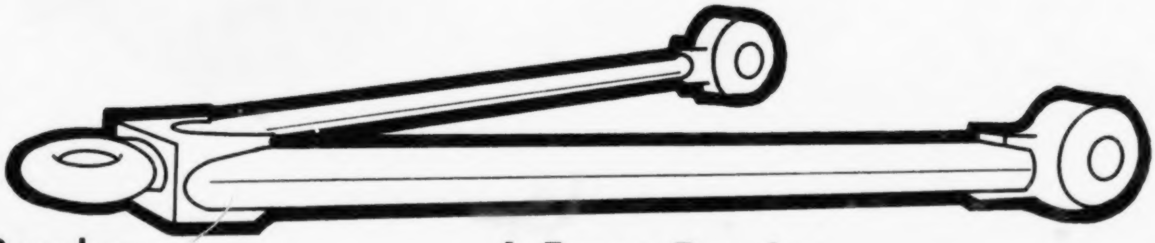
Visual 12.9

Drawbars



Straight Drawbar

Drawbar
Eye

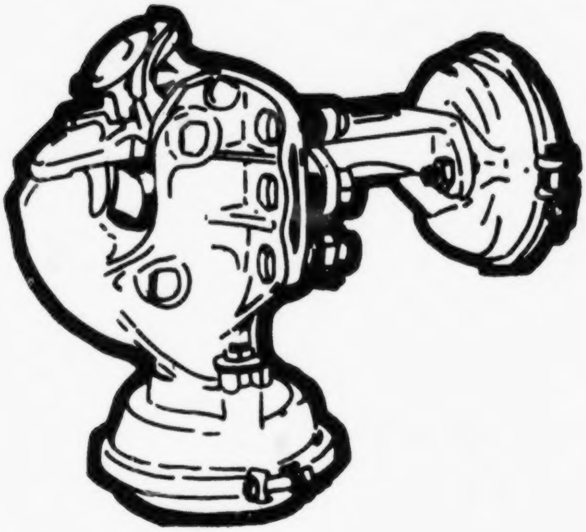


Drawbar
Eye

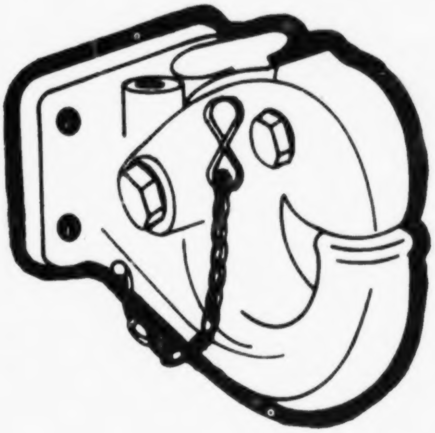
A Frame Drawbar

Visual 12.10

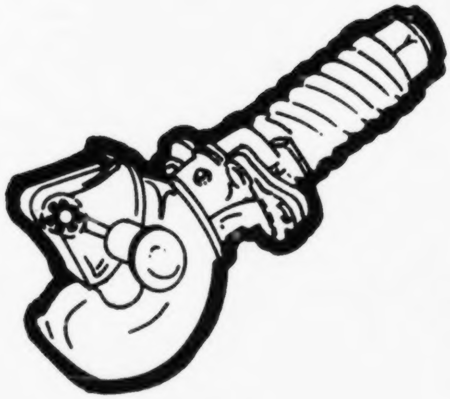
Types of Pintle Hooks



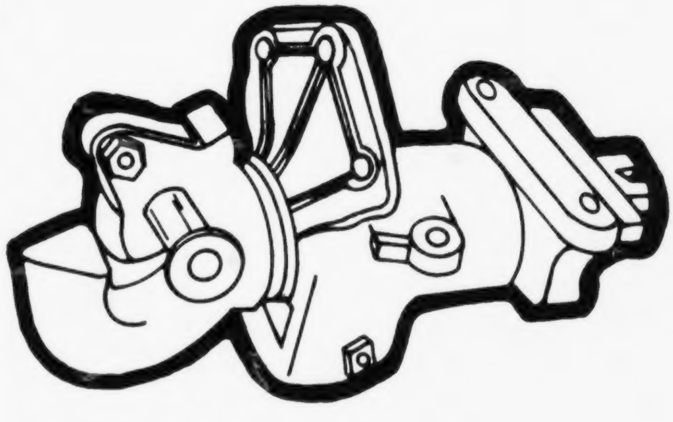
Air



Rigid

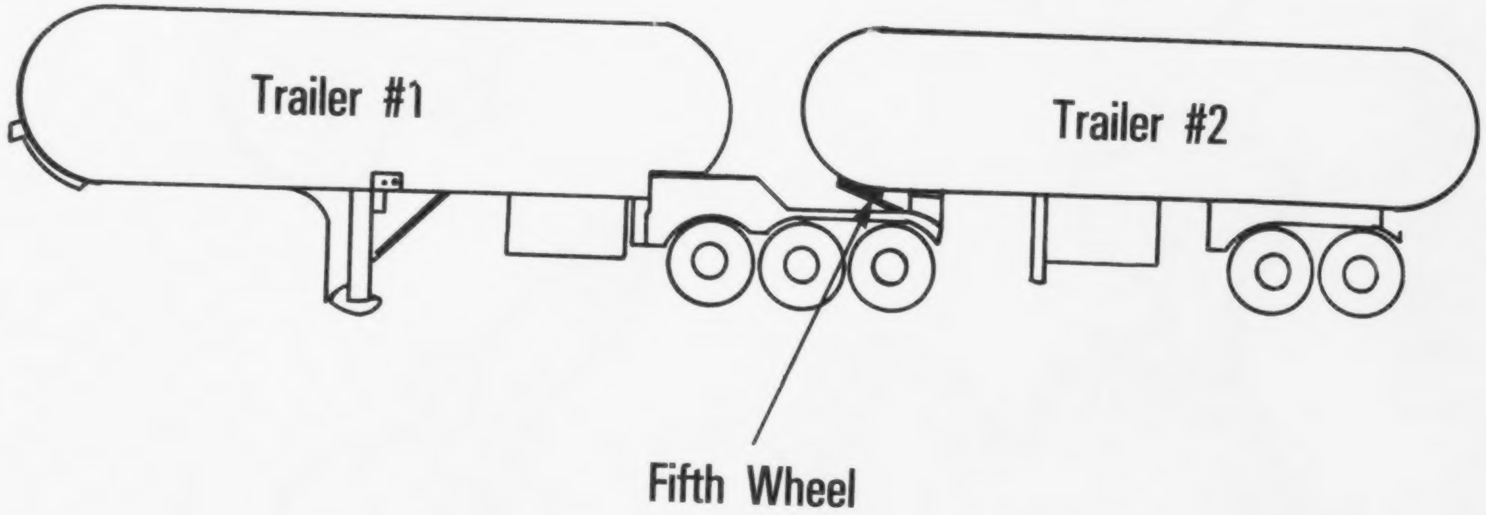


Spring



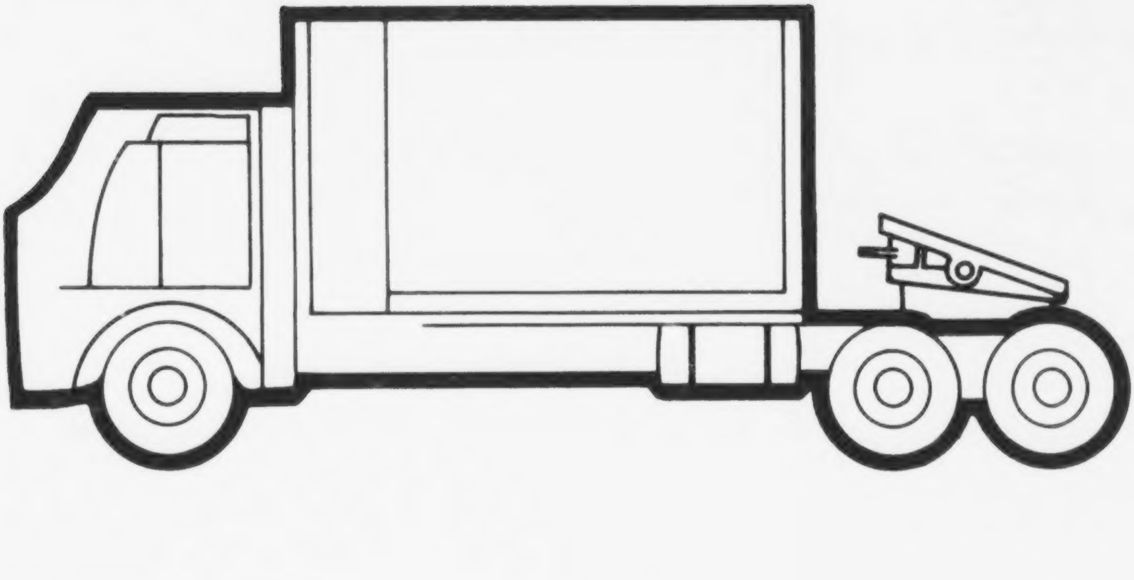
Swivel

B-Trains


Trailer #1
Trailer #2
Fifth Wheel

Visual 12.12

Dromedary Tractor



LESSON 2 VEHICLE SYSTEMS DEMONSTRATION (Lab)

Overview

Time Allotted; Two hours

Prerequisites: Unit 4.1, Lesson 1

Purpose:

The purpose of this lesson is to allow students to demonstrate their knowledge of vehicle systems and components gained in the previous lessons. By providing a "hands on" understanding of vehicle systems, the lesson also serves as a "bridge" to the next two units, dealing with servicing of the vehicle and diagnosing malfunctions.

Materials

Instructional Aids

None

Student Material

No additional material required

Instructor Material

Vehicle Systems and Components Checklist (at end of this lesson)

Equipment:

Several different types of tractors and semi-trailers should be available to demonstrate as wide a range as possible of various engines, drive trains, brake systems and coupling devices. It would be helpful if the school could arrange to borrow tractor-trailers that students have not yet seen up to this point or else to conduct this session at a truck stop, used truck dealership, etc.

A pointer, flashlight and wiring rags for use in demonstration.

Facilities:

This lesson may take place in any area permitting students access to all portions of a tractor and trailer. An indoor facility is preferred becuase of the opportunity it provides to schedule the lesson without regard to weather.

A maintenance facility with a servicing pit or lift is highly desireable in order to allow the underside of the vehicle to be viewed by an entire group at a time.

Content

Activity or Topic	Approximate Time
1. VEHICLE SYSTEMS DEMONSTRATION	2 hours

1. VEHICLE SYSTEMS DEMONSTRATION (2 hours)

Purpose

The purpose of this lesson is to allow students to locate and identify the vehicle system components and to evidence their knowledge of component purpose and function.

Range Layout

No specific layout required.

Directions

1. Class will be divided into small groups. Perferably a student teacher ratio of one to four or one to five will be used.

2. Each lab session will be divided into two parts.

   A. Instructor demonstration--Instructor wil point out and identify a particular vehicle system and its major components.

   B. Student demonstration--After the Instructor demonstration, the instructor will name a component to be identified. The students will be asked individually to locate and identify the component and briefly describe its purpose and function.

3. The instructor should utilize the vehicle systems component checklist that is provided in order to assure that all components are covered. The tractor and trailer will be approached by area of the vehicle rather than by system. Since some systems are spread across several portions of the vehicle, a system-oriented approach would require unnecessary movement. Moreover, different groups working on the same vehicle would get in one another's way. An area by area approach makes it particularly important to use the checklist.

4. The order in which the various areas are dealt with during the Instructor and Student demonstrations is left entirely up to the instructor, and will depend upon such factors as:

   Number of groups--If more than one group is using a vehicle at the same time, each will have to start in a different area.

   Access to underside--If access to the underside of the vehicle requires use of a lift, then those portions of both Instructor and Student demonstrations dealing with the underside of the vehicle should be conducted at one time for all students.

Observation

The instructor will make note of students who have difficulty in locating, identifying, or explaining certain components. Particular attention should be given to detecting misconceptions, including consistently:

- mistaking one component for another.
- going to the wrong part of the vehicle to find a component.
- mistaking the purpose and function of one component with that of another.

The instructor should also watch for students who provide a memorized explanation of purpose or function without reflecting true understanding.

Evaluation

Since there are no performance objectives for this Unit, there are no specific criteria to be used in assessing students. However, probing questions should be asked in order to assess understanding. Students who lack true understanding should be referred to their Student Manuals and should also be reported to the school administration for remedial instruction.

Notes:

UNIT 4.1 VEHICLE SYSTEMS AND COMPONENTS CHECKLIST

Frame, Suspension and Axles

- Tractor and Trailer Frame
  - Frame rails
  - Cross members
  - Engine mounts
  - Suspension hangers
  - Body supports
  - Gussets
  - Fuel tank supports
- Springs (Leaf, Coil, Air, or Torsion Bar)
- Shock Absorbers
- Torque Rods
- Shackles

Engines

- Crankcase containing:
  - Cylinders
  - Pistons
  - Connecting Rods
  - Valves
  - Crank Shaft

Fuel Systems

- Storage Tanks
- Fuel lines (main and return lines)
- Filters
- Fuel Pump Carburetor*
- Injectors and Injector Pump
- Accelerator

Air Intake Systems

- Air cleaner
- Rain cover
- Turbochargers
- Superchargers
- Blower
- After cooler

Exhaust Systems

- Exhaust manifold
- Exhaust pipe
- Turbocharger
- Muffler
- Pyrometer

Lubrication Systems

- Oil
- Oil pan
- Filter(s)
- Oil Pump
- Dipstick
- Filler cap

Cooling Systems

- Coolant
- Radiator and hoses
- Radiator cap
- Fan and belts
- Water pump
- Filters
- Thermostats
- Water jackets

Electrical Systems (Cranking, Charging, Lighting and Auxiliary Accessory)

- Batteries and cables
- Alternator or Generator
- Spark plugs and wires*
- Coil*
- Distributor*
- Voltage regulator*
- Starting motor
- Ammeter
- Voltmeter
- Fuses
- Circuit breakers

Drive Trains

- Clutch
- Transmission (Main and Auxillary)
- U-joints
- Propeller shaft
- Rear axle, differential

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* Gasoline engines only

Brake Systems

Brake chambers
Disk and/or drums
Slack adjusters (Manual and Automatic types)
Push rod
Adjuster nut
Spring brake assembly
Air compressor and governor
Air reservoirs (Drain cocks, safety valves)
Air dryers and aftercoolers

Wheels, Bearings, Rims and Tires

Tires:
    Construction type (radials, bias ply)
    Tread types (rib, cross lug, mud and snow
    Size (tire markings)
Rims (single and multi-piece)
Wheels (disk or spoke)
Lug and wheel nuts

Steering Systems

Manual and power steering types
Steering shaft
Gear box
Pitman arm and drag link
Tie rod
Steering arms
Steering knuckle and spindle
Kingpin
Cruise control systems

Coupling Systems

Fifth wheel (locking mechanism, slack adjuster, release handle)
Upper fifth wheel plate
Kingpin
Landing gears
Pintle hooks
Dolly eyes
Safety chains
Converter dolly

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